

MARCH TO MAY 1985

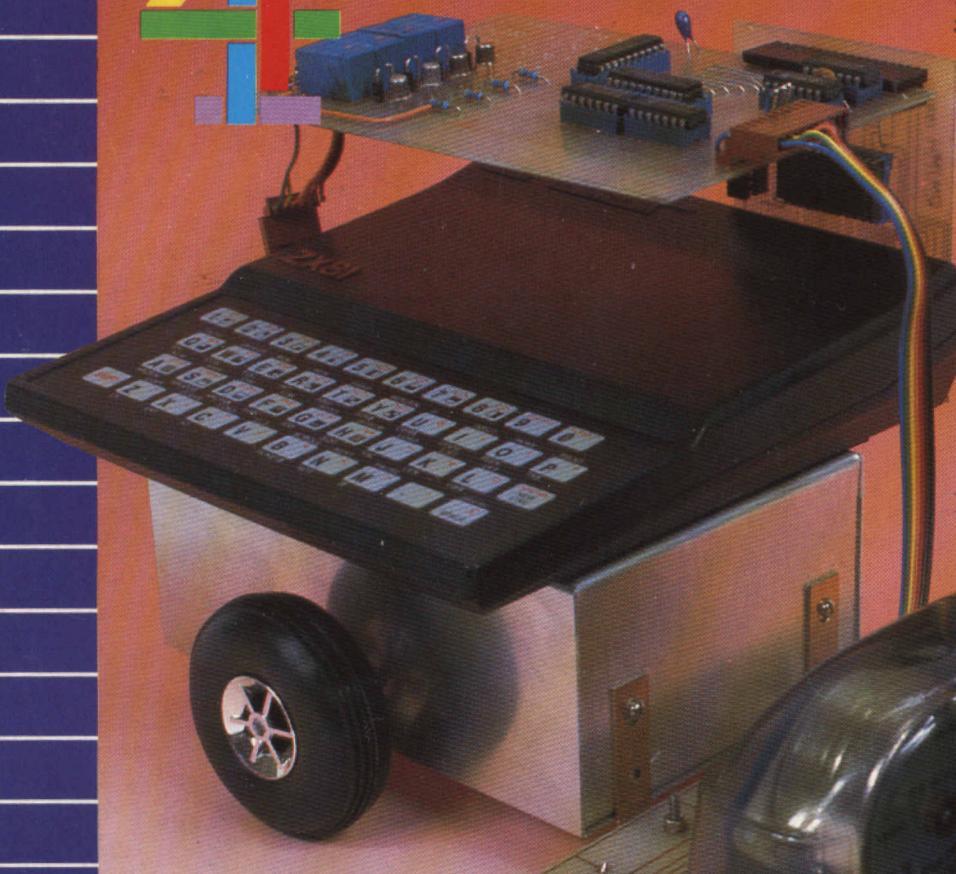
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# electronics

THE MAPLIN MAGAZINE

MARCH TO MAY 85  
VOL. 4. NO. 14

## 4 THE CHANNEL FOUR RC FULL CONSTRUCTION DETAILS

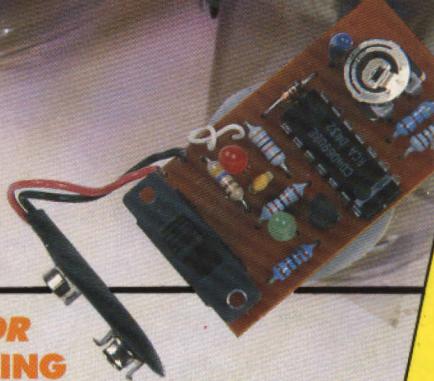


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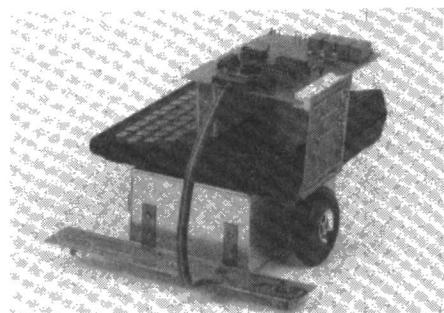
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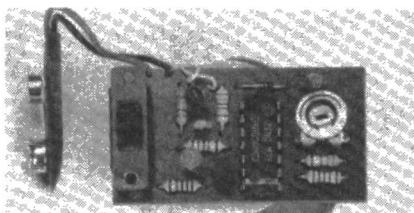
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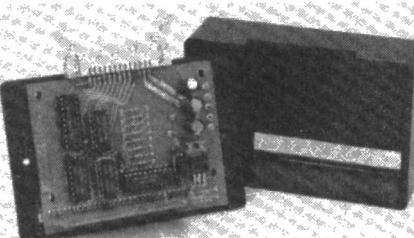
Full construction details of the robot featuring in Channel 4's '4 Computer Buffs' every Monday at 5 p.m. for six weeks, commencing 11th February.

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Use the free PCB on the cover to start building this fascinating new project. It's an invaluable aid for the handyman and anyone can build it.

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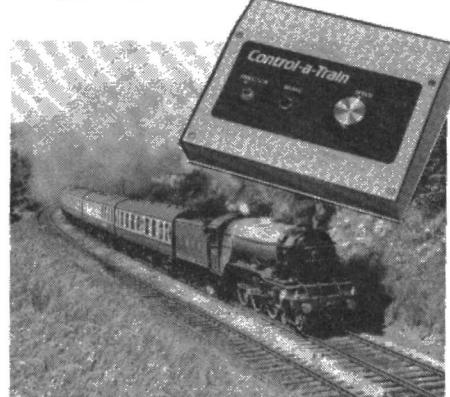
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# Electronics

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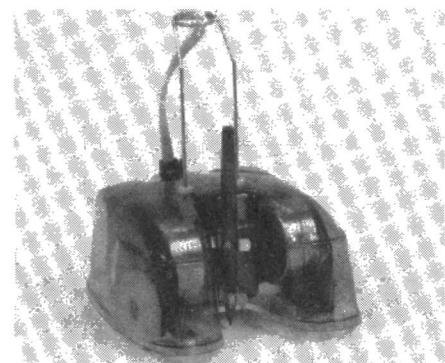
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We very much regret that the last part of this series has had to be held over due to lack of space. It will be concluded in our next issue.

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# LIVE-WIRE DETECTOR

MAPLIN  
LIVE-WIRE  
DETECTOR

**FREE GIFT  
FRONT COVER  
PROJECT**

by Dave Goodman

The Maplin Live-Wire Detector is a fascinating and novel device which will detect the presence of mains electricity whether there's a current flowing or not. It's better than neon screwdrivers or multimeters because you do not have to make contact with the wire - it signals the presence of mains up to two inches (5cm) away and better than metal detectors, because it only indicates if the wire is live; also, its considerably cheaper.

## A Most Useful Instrument

It's the sort of device every household should own and anyone can use it because you don't have to actually touch dangerous points with any part of the Live-Wire Detector. Even if the wires are not connected to anything at one end, Live Wire will tell you if they're live. You could use it to find buried wires in dry plaster or plastic conduit or under floor or ceiling boards, though keep in mind that its sensitivity is only about two inches, so don't put a four inch nail where there was a negative reading! However, if you get a positive reading of a wire in a wall and there's nothing else electrical on that wall, then you can hammer the nail home with confidence anywhere else. The message then is: beware of negative readings.

Other uses of Live Wire include detecting breaks in cables or appliance leads. If you have a suspect mains lead, plug it into the mains; run Live Wire along the cable and at the point where the live wire is broken, Live Wire will cease to sound and flash. If a fuse blows, Live Wire will indicate mains present up to all

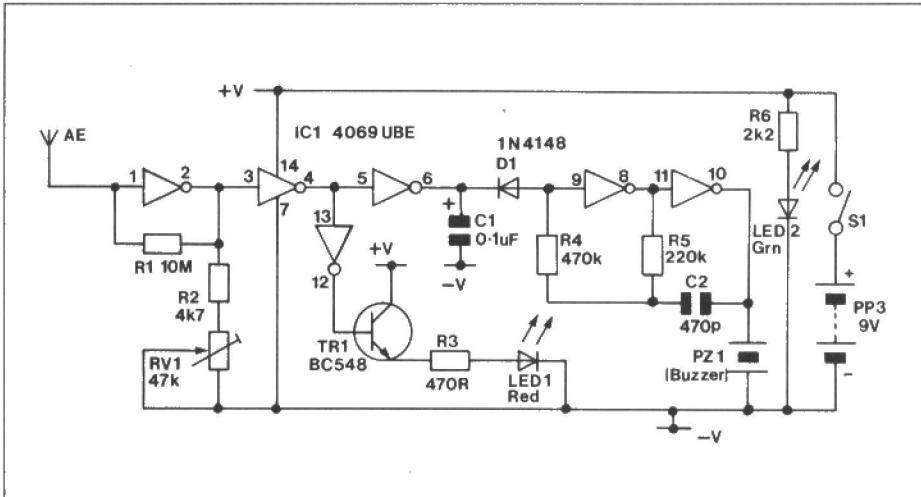
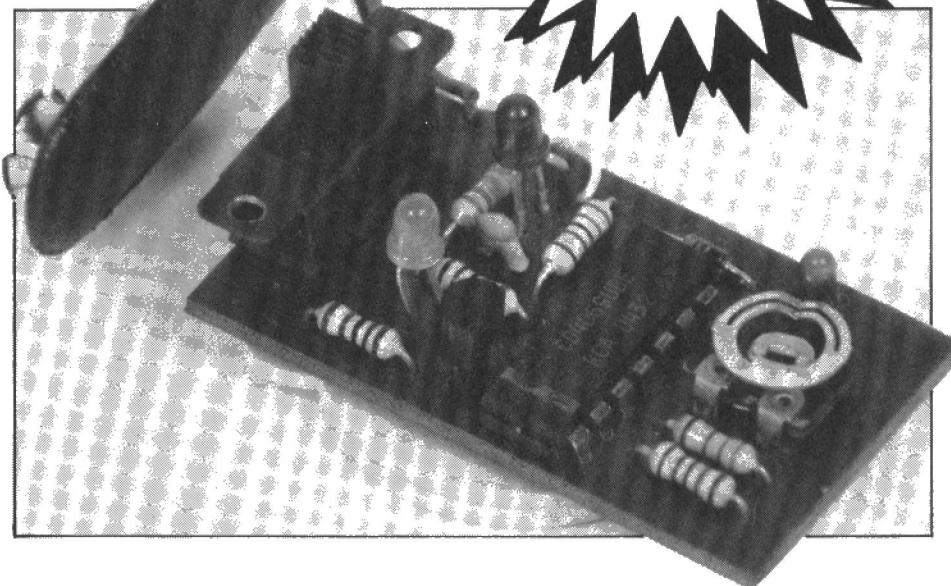


Figure 1. Circuit Diagram

the fuses and mains present on the wires leaving every fuse except the dead one. If you're wallpapering and need to remove a switch plate, first check that you get a positive reading with the mains on, then switch off or remove the fuse from the circuit you think is the right one. With Live Wire in the same position as before, it will no longer sound if you've found the right circuit. There are probably hundreds of other uses and one or two we've thought of include detecting ringing on telephone lines, detecting the EHT in TV sets (though Live Wire will probably need to be desensitized).

Live Wire will also detect static electricity but in this case, it must be moved into or through the static field and only while it is moving will the instrument sound.

## Circuit Description

An AC electro-magnetic field is detected at IC1 pin 1. The 4069 inverter is connected in a linear mode by placing a feedback resistor between pins 1 and 2. The value chosen for R1 keeps the characteristic high CMOS input impedance so that changes in the surrounding electro-magnetic field produce a minute voltage change on the aerial track which are massively amplified in this stage.

RV1 sets the point at which the output from IC1 pin 4 will trigger the next two stages. This is necessary since the quiescent voltage at pin 2 will be different from one chip to another. Being a digital chip, this usually makes no difference but in linear mode, it is significant and RV1 has to be present to ensure that every Live Wire can meet the specification. RV1, therefore, is adjusted to keep pin 4 high when not triggered.

Turning S1 on, lights LED2 which indicates that the circuit is active. If no electro-magnetic field is detected, then pin 4 will be high and the rest of the circuit is inactive. When an electro-magnetic field is detected, pin 4 goes low and pin 12 then goes high causing the emitter-follower TR1 to conduct, operating LED1.

At the same time, IC1 pin 6 goes high. D1 will now be reverse-biased which removes the continuous low 'hold-off' condition from pin 9 and allows the oscillator to run. The oscillator comprises the final two stages of the 4069 and resistors R4, R5 and C2. The approximate frequency is 3.5kHz. The output of the oscillator drives the high impedance piezo-ceramic buzzer directly.

The circuit runs from a 9V PP3 battery. The current drain is approximately 10mA when the circuit is switched on and 17mA when it is detecting electricity.

An AC electro-magnetic field is one which is collapsing and re-establishing itself in phase with the frequency in the wire, e.g. for UK mains, it is 50Hz. This has the effect of turning D1 on and off, which stops and starts the oscillator, giving a characteristic buzzing sound. If the circuit was moved in a static electro-magnetic field, it will produce a pure

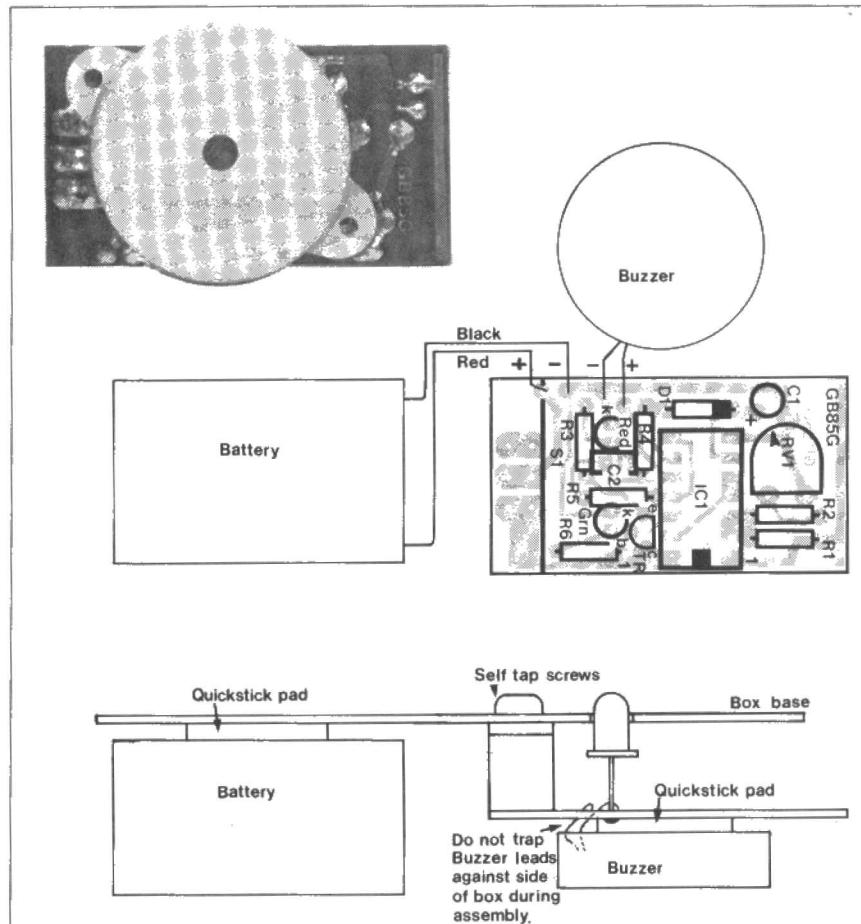


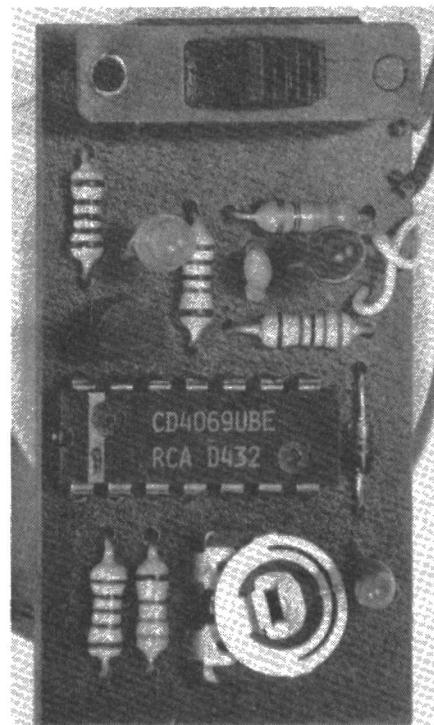
Figure 2. Board Overlay, Wiring and Assembly

high frequency tone.

As the circuit moves into a field, LED1 may operate before the buzzer starts to sound. It will gradually increase in brightness and during this time, at some point, the buzzer will sound before or just as the LED reaches full brightness.

## Construction

This project is very easy to build and



even an absolute beginner should have no problems provided that you can solder properly. Briefly, the important points to note when soldering are: ensure the tip of the iron is always covered with a thin layer of resin-cored solder; ensure that the tip of the iron is in contact simultaneously with both sides of the joint, i.e. in this case, the track on the PCB and the component lead; apply the solder to the joint, not the tip of the iron; remove the iron immediately the solder starts to flow; keep the tip of the iron clean by wiping it regularly on a damp sponge. A good solder joint will have a perfectly smooth shiny appearance and be shaped like a cone. Good soldering is an art which must be learned, so if you've never soldered electronic components before, buy a small piece of Veroboard and some tinned copper wire and practise until you have perfected the art.

With reference to Figure 2 and the Parts List, fit the resistors into the positions shown. It does not matter which way round each resistor is inserted but the correct value must be put in the right place. The resistors are identified by the coloured bands on their bodies as follows:

R1	10M	Brown	Black	Blue	Gold
R2	4k7	Yellow	Violet	Red	Brown
R3	470R	Yellow	Violet	Brown	Brown
R4	470k	Yellow	Violet	Yellow	Brown
R5	220k	Red	Red	Yellow	Brown
R6	2k2	Red	Red	Red	Brown

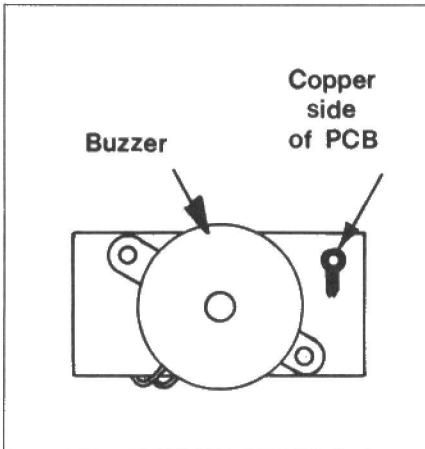
Next, insert the diode in position D1. This component must be the right way round; the thick band at one end of the body must line up with the thick band on the legend (the end closest to C1). These seven components should be pressed flat to the PCB as shown in the photographs.

C2 will be marked n47 or 470p and should be fitted in the position shown. It does not matter which way round it is inserted. It is important, however, that C1, the remaining capacitor, is inserted the right way round. It has one lead longer than the other and has a '+' symbol marked on its body. It should be inserted in the position marked C1 on the legend with the long lead (positive '+') in the hole marked '+' on the board. Carefully solder in all these components and clip off the excess lead ends.

Now insert IC1, so that the 'D' shaped cut-out in one end is the same way as shown in the legend. If the IC does not have the cut-out, it will have a small dot printed or embossed in one corner indicating pin 1 and this must be inserted so that it is next to the 'I' shown on the legend. Another way to find pin 1 is to place it so that the writing on the package is the right way up and reads correctly; now pin 1 will always be the lower left pin on the package.

Fit TR1 such that its three leads go through the three holes marked C, B and E on the legend and such that the 'D' shape of the package is orientated as on the legend. Fit preset RV1 in the position indicated. Carefully solder all the leads of these three components and cut off the excess leads of the transistor.

The red LED is LED1. The shorter lead is the cathode and the edge of the circular package base is flattened adjacent to this lead. This cathode lead must be inserted in the hole marked 'k' in the position marked 'RED' on the legend. The longer lead is inserted into the hole next to it. The green LED is LED2 and is fitted as for LED1 in the position marked 'GRN' with its short lead in the hole marked 'k' on the legend. Adjust the two LED's until the base of each coloured package is 6mm above the top surface of the board. Holding the LED's absolutely vertical in that position, solder the four



**Figure 3. Buzzer Mounting**

leads and clip off the excess wire.

Now fit switch S1. It does not matter which way round it goes but it must be perfectly vertical with respect to the board. Carefully solder it in position.

Cut the wires on the battery connector about two inches (5cm) from the clip and strip  $\frac{1}{8}$  inch (3mm) of the insulation from each wire. Twist the strands of each lead and then tin the two wires (i.e. apply the iron to the bare wire and the solder to the bare wire and remove the iron when the solder flows around and between the strands of the wire). The red wire from the battery clip should be inserted into the hole shown '+ red' on the legend and the black in the hole marked '- black'. Solder these two wires to the PCB.

Cut the wires from the buzzer about 1 inch (2½cm) from it. Strip  $\frac{1}{8}$  inch (3mm) of the insulation from each lead and tin each wire as before. These two wires should now be inserted either way round, in the two remaining holes on the PCB as shown in the legend. Solder them in position.

Check each solder joint carefully to ensure that it is a good joint as described earlier. Ensure that there are no tracks joined together by blobs or fine lines of solder where there should be no connection. Finally cross-check each component on the board with the Parts List, Figure 2 and the photographs, to ensure that each component is in the right place and the right way round.

## Final Assembly and Testing

With reference to Figure 3, stick the buzzer precisely centrally onto the soldered side of the PCB using a sticky-pad so that the mounting ears of the buzzer point to the corners of the PCB and the wires come out of the buzzer right on the edge of the board. Ensure that the sticky-pad is fixed to the base of the buzzer, not the side with the large central hole in it.

With a small screwdriver or trim tool, adjust RV1 until its wiper points to C1 as shown in Figure 2. Push the assembly into the box so that the switch protrudes through the rectangular hole and the two LED's protrude through two of the round holes. Line up the switch fixing holes with the other two holes in the box and screw the two self-tapping screws into the switch. Just one or two turns to stop the assembly falling out will be sufficient at this stage. If you need to readjust the buzzer position to get it to fit in the box, simply peel up the sticky-pad – it may be stuck and unstuck many times before it loses its stickiness.

Plug the battery onto the battery clip making absolutely certain it is the right way round or IC1 could be damaged. For now, drop the battery loose into the box. The unit may now come on signified by the green LED lighting, depending on the position of S1. Switch off if necessary. Plug an appliance into a mains socket and switch the appliance on. Bring the assembly up to the cable, holding the battery end of the box. Switch on. The green LED will light and stay on. As you approach the appliance's cable, the red LED should light and the buzzer sound.

RV1 must now be adjusted so that the unit starts to operate about 2 inches (5cm) from the cable. To increase the sensitivity, turn RV1 clockwise. Do not try to make the unit too sensitive or you will find that occasionally it triggers for no apparent reason or depending on how you move your hand around near it.

When RV1 is correctly adjusted, tighten up the two self-tapping screws. Then fix the battery into the box using the other sticky-pad. Finally, screw the box lid on using the four screws provided.

## LIVE-WIRE DETECTOR PARTS LIST

### RESISTORS: All 0.4W 1% Metal Film, unless specified:

R1	10M 5% Carbon Film $\frac{1}{2}W$	1	(B10M)
R2	4k7	1	(M4K7)
R3	470Ω	1	(M470R)
R4	470k	1	(M470K)
R5	220k	1	(M220K)
R6	2k2	1	(M2K2)
RV1	47k Hor. sub-min Preset	1	(WR60Q)

### CAPACITORS

C1	0.1μF 35V Tantalum	1	(WW54J)
C2	470pF Ceramic	1	(WX64U)

### SEMICONDUCTORS

TR1	BC548	1	(QB73Q)
D1	IN4148	1	(QL80B)
IC1	4069UBE	1	(QX25C)
LED1	Red LED	1	(WL32K)
LED2	Green LED	1	(WL33L)

### MISCELLANEOUS

S1	Sub-min Slide	1	(FH38Q)
	Battery Clip	1	(HF28F)
	Mini Sounder	1	(FM59P)
	Self tapper No.4 x $\frac{1}{2}$	1 Pkt	(BF65V)
	Live-Wire Detector Case	1	(FT39N)
	Quickstick Pads	1 Strip	(HB22Y)

### OPTIONAL

B1	Live-Wire Detector P.C.B.	1	(GB85G)
	9 Volt Battery (PP3)	1	(FK58N)

A kit containing all parts excluding optional items is available. Order As: LK63T Price £2.95

Also available separately but not shown in the 1988 catalogue:

Live-Wire Detector P.C.B. Order As: GB85G Price 50p

Mini Sounder Order As: FM59P Price 78p

Live-Wire Detector Case Order As: FT39N Price £1.10

# ELECTRONIC CHRONICLES

## A Brief History of Electronics

Part 5

### The History of Television

by Mike Wharton

#### Moving Pictures

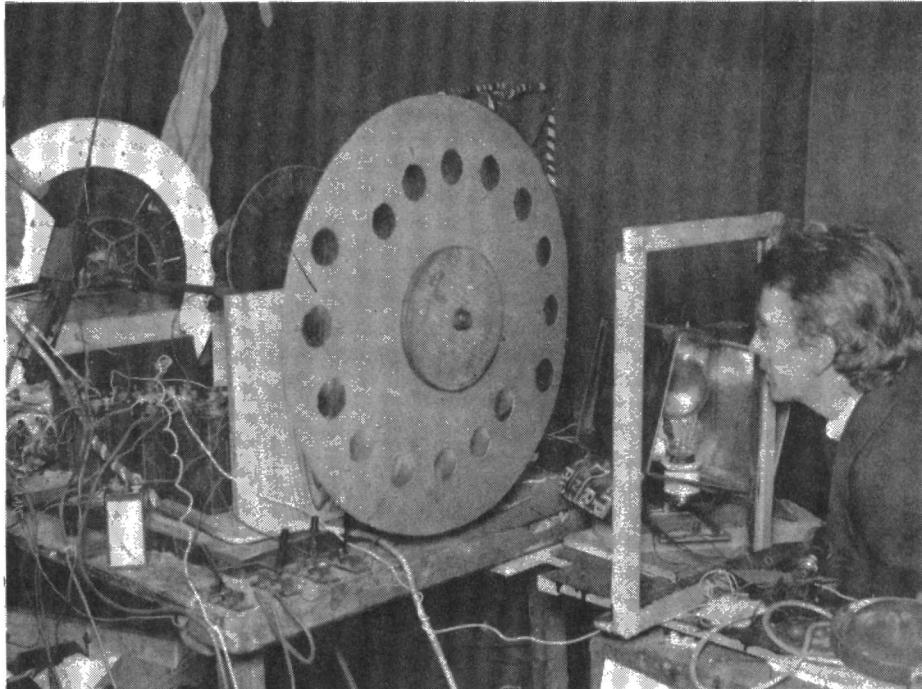
The modern TV is the culmination of many years of research and development. The origin of the more important components can be traced back to the earliest beginnings of electronics during the 19th century. The advent of broadcast radio during the first decades of this century provided the impetus to transmit pictures along with the sounds.

The techniques adapted for films could be used as the basis for a suitable process, that is to 'freeze' the action for an instant. The illusion of motion is re-created by the repeated showing of these stills and the effect of persistence of vision. One of the major problems which had to be overcome was to translate the pattern of light and shade in a scene into a corresponding signal voltage as the first stage in any electrical transmission system. This could then be converted into a radio signal for broadcasting to suitable receivers.

#### Cameras

One of the first methods employed was to use a large number of photo-cells arranged in a matrix; light from a portion of the scene was thus converted by each cell and the information could be sent along a number of wires, one for each cell. At the receiving end, the brightness of small light bulbs would be varied in sympathy with the photo-cells to re-create the original scene. The system as envisaged would have produced the type of picture which it has taken modern computer technology to generate and is often seen at football stadiums to produce a large display. The drawbacks to this idea as a method of transmitting moving pictures are two-fold; the first is that the resolution of the final picture is governed by the number of photo-cells used in the 'camera'. Secondly, the more cells that are used, the greater the problem of transmission, since this is essentially a parallel processing method and successful transmission by radio requires a serial method.

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Baird in his laboratory testing his transmitter and receiver in March 1925

#### Scanning Converters

The solution to this part of the problem lay in scanning the scene in some way, so that the light levels are converted into a continuously varying voltage. A method invented by Nipkow used a disc onto which were fitted a number of lenses, arranged in a spiral, as shown in Figure 1. By using this disc with a single light cell, it was possible to convert the scene into a number of curved 'lines'. The light from each lens was directed onto the cell, which thus produced a varying voltage according to the light level being scanned. The scene could then be transmitted in a serial form and re-created at the receiving end by a method which was like the reverse of the encoding process. Here a second Nipkow disc was used which directed the output from a light source onto a frosted glass screen with the signal being used to modulate the light.

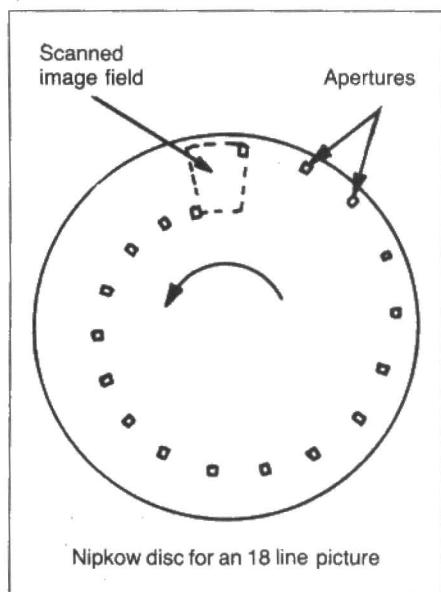


Figure 1. Mechanical scanning device.

## BAIRD

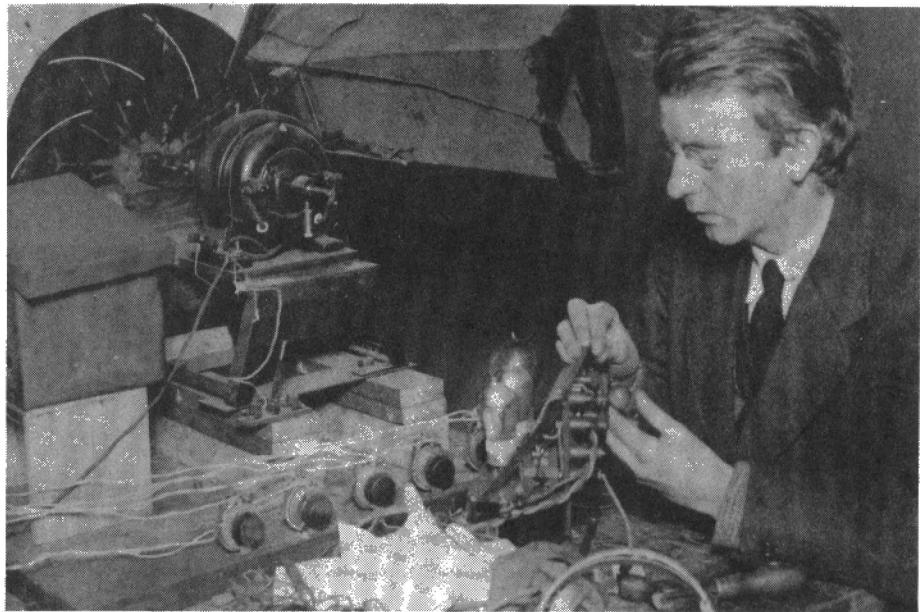
The above method is, in essence, that used by J. L. Baird for his demonstration of the first practical television system during the early 1930's. Of course there are many problems involved in the implementation of this method; for example, it is necessary to maintain the two Nipkow discs in exact synchronism and this may be achieved by inserting a synchronisation pulse at the end of each line, thus producing what would now be regarded as a composite video signal. The other problem which Baird faced was that of finding a suitable light source for the receiver. In this case, the requirement was for something which had a high intensity output, since it was being used in a similar fashion to a projector lamp. A filament bulb was totally unsuitable, though, since a second requirement was for high frequency response in order to reproduce the variations of light and shade at the speed generated by the scanner. In the end, he was forced to use a form of glow discharge lamp, rather like a neon bulb. This was in order to obtain the necessary frequency response but inevitably meant that the brightness and contrast of the screen was fairly low.

When Baird tried to interest the broadcasting authorities with his system, he was then faced with a further imposed constraint. The BBC decided that the transmissions would be in the Medium Wave-band and allowed him a channel bandwidth of 9kHz! This may be compared with the modern colour TV channel bandwidth of around 6MHz; admittedly Baird's original system did not include colour but it gives some idea of the scale of the problem he faced. Since this electro-mechanical system was eventually overtaken by the all-electronic systems, there has been a tendency in recent years to de-bunk Baird and claim that his contribution to the development of television was actually negative due to his pursuit of a system which was primitive and 'obviously' could never work. It was certainly not obvious at the time that this method would be superseded by the continuing advance of electronics. It may well be that his greatest contribution was to show that a system of transmitting moving pictures by radio was possible and could be made to work, despite the doubts expressed by the scientists of the day.

## Electronic Systems

The various elements required to make up the electronic version of Baird's concept of TV had been around for some time, but had not been developed or put together as a complete system. Let us look at some of the more important items in turn.

The mechanical scanner has been replaced by the electronic camera, where an electron beam is used to scan the scene and produce a video signal. An early version of such a device had been invented in 1923 by Count Vladimir



Baird adjusting his television transmitter

Zworykin, which he called the Iconoscope, (from the Greek ikon, a picture and skopein, to see), shown in Figure 2. The target was an aluminium film oxidised on one side, which was photo-sensitized by caesium vapour and faced a metal grill which served as a collector for photo-electrons. The metal plate was scanned by an electron beam, which penetrated through the oxide layer, forming a temporary conduction path permitting the locally stored charge to flow off through the signal plate.

The advances in electronics which were taking place at the same time allowed the signal produced by the orthicon to be processed much more easily than was the case with a mechanical system. The improvements in valve techniques made the amplification of the video signal generated a real possibility, and hence generally improved the quality of the system.

## Cathode Ray Tubes

At the receiving end of the system, an improvement over the disc scanner was also needed to make full use of the much improved resolution possible with the electronic cameras. In fact, the original orthicon camera came out of studies into the nature of the so-called cathode rays and the cathode ray tube was another extension of this work.

This had originally begun during the middle of the 19th century, by investigators like Crookes and Faraday. For example, Crookes had shown that an electric current could be persuaded to flow through a gas provided the voltage was sufficiently high and the gas pressure very low. He also showed that the flow of electricity through the gas was like rays of light, in that they travelled in straight lines; his famous maltese cross experiment, shown in Figure 3 demonstrated this. Here the rays emanated

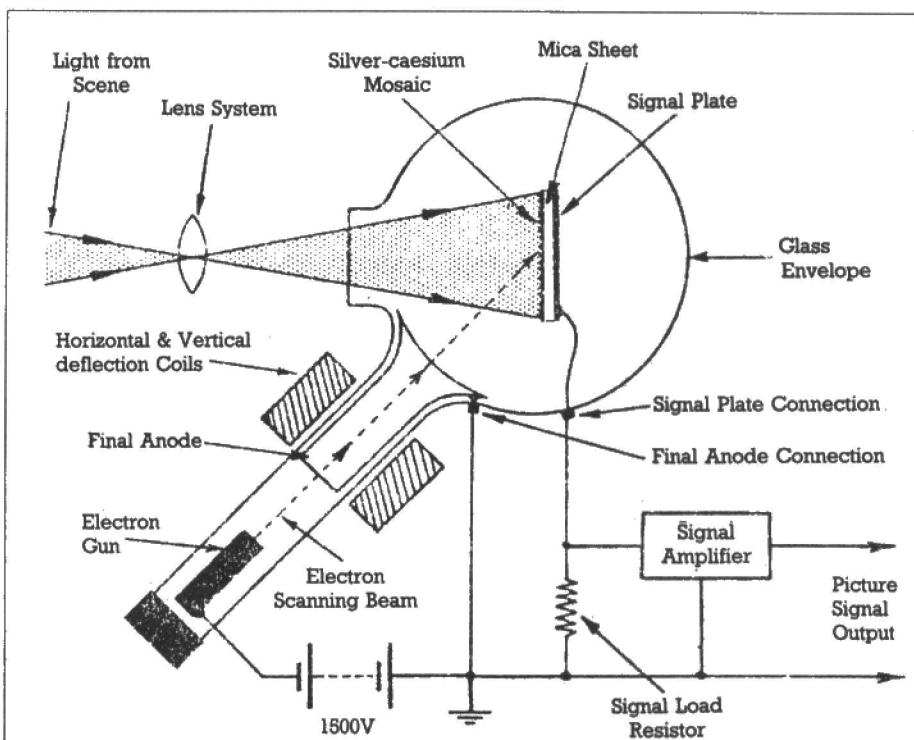


Figure 2. The Iconoscope.



BBC Hulton Picture Library

Sir William Crookes 1832 - 1919

from the negative electrode, or cathode, and cast a shadow of the cross on the end of the tube. In these early experiments, the rays were probably of negative ions, formed by the electrons from the cathode being captured when they hit a gas atom. These ions would then be attracted to the positively charged anode, and being relatively massive, would fly past to form the 'shadow' on the end of the tube. It was also possible to see these rays as the gas atoms fluoresced due to the internal rearrangement of electrons within them.

By improving the vacuum within the tube, the cathode rays tended to disappear, due to the removal of the gas atoms responsible for fluorescence. This meant that the electrons then had a greater free path and conduction through the tube was due mainly to them. Experiments into the effect of bombarding various substances with cathode rays had shown that some exhibited phosphorescence, that is, emitted light which persisted for a short while after the excitation had ceased. By placing a layer of such material over the end of the tube, the position of the beam was again revealed. Also, it was possible to deflect the beam of electrons by both electrostatic and magnetic means. By placing a pair of plates on either side of the beam path and applying a voltage across them, electro-static deflection of the beam was achieved. All of this led in 1897 to the production of the first cathode ray oscilloscope by Ferdinand Braun at the University of Strasbourg.

At around the same time, there had been various improvements to the electron gun. One of the first of these was due to a man by the name of Wehnelt in 1905. He introduced the thermionic cathode into the cathode ray tube, thereby increasing the beam current possible. He also devised the idea of placing a small metal cylinder, closed at one end except for a small hole around the cathode, which forced the beam down to a smaller diameter. The use of such a Wehnelt cylinder permitted a smaller spot of light to be produced on the screen and hence improve the resolution. Further advances were to place a number of cylindrical electrodes along the path of the beam; by making these positive with respect to the

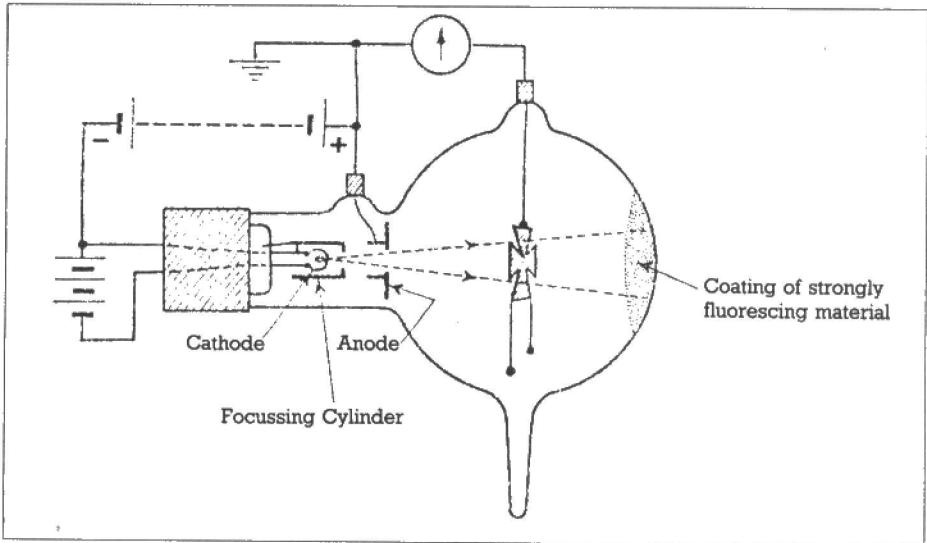


Figure 3. The Maltese Cross experiment.

cathode, the electrons were accelerated towards the screen at higher speeds thus increasing the brightness of the light spot. It was found that adjusting the potentials of these anodes allowed the formation of an electron lens, allowing the beam to be focused even more finely on the screen and enhancing the resolution further. The whole assembly is called an electron gun and a typical one is shown in Figure 4.

The cathode ray tube, as it was and still is called, was an almost perfect solution to the problem of reproducing the transmitted TV picture. One of the first experiments in using a CRT to produce a picture had been carried out during the early 1930's by the German worker Baron von Ardenne. His initial idea was to use what is called velocity modulation; that is the light and dark areas of the picture are generated by altering the speed of the spot across the screen. It became apparent that the same effect could be achieved by applying the picture modulating voltage to the cathode and scanning at a constant speed. The application of a variable negative voltage to the Wehnelt cylinder, or the 'grid' as it is now called, also allowed the overall brightness of the picture to be altered. During the intervening years there have been many more innovations and modern CRT's employ magnetic deflection but it has remained unchanged in virtually all other respects from the early versions.

The electronic TV system which

originated during the 1930's was really due to the combined effort of a team working for the EMI Company, under the direction of A. A. Campbell-Swinton. He had originally put forward the ideas for a system for the remote transmission of images as early as 1908. His scheme was to use cathode ray tubes both for the transmission and the reception of the pictures, an idea which had to wait for the technology to provide him with the necessary hardware. Indeed, the first idea of the possibility goes back one year to 1907, when a Russian, Boris Rosing, seemed to have thought of using Nipkow disc scanning and the use of the newly invented oscilloscope tube for reception. During the intervening twenty years, little or no development of these ideas was carried out, although Campbell-Swinton elaborated on them in 1911 and again in 1920. The interest aroused by Baird gave the necessary impetus for the application of the available electronics to the problem.

Although 405-line transmissions were started by the BBC during the mid-1930's, the outbreak of war in 1939 brought TV broadcasting to an abrupt halt. The Second World War was responsible for many advances in the field of electronics and these were available for application to television after the war.

In the final article in this series, we shall take a brief look at the people responsible for the development of the modern digital computer.

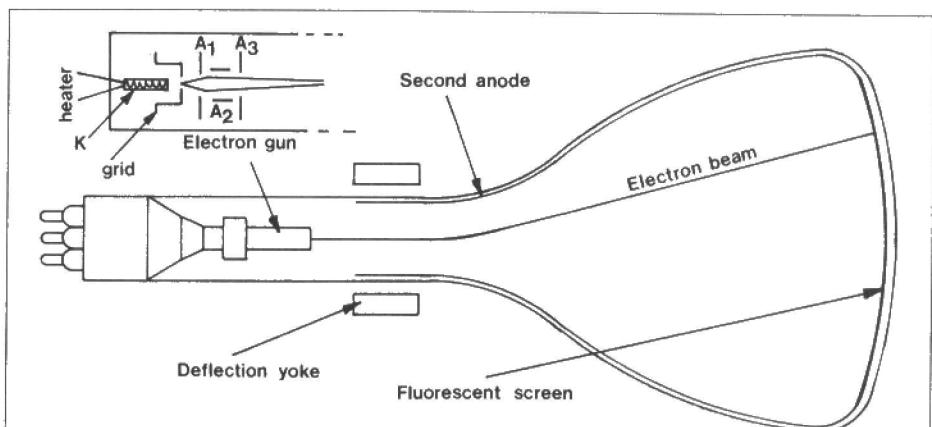


Figure 4. A CRT electron gun.

# SPECTRUM I/O CONTROLLER

by Dave Goodman

- Buffered 2 Way 8-Bit Data Bus
- 8 Control Lines
- Access Made Via Keyboard  
'IN' and 'OUT' Commands  
or From Machine Code



Prompted by the many requests received from our customers for a series of interfaces allowing add-on expansion to the Spectrum computer, the I/O Controller module is offered to achieve this. Although not a programmable parallel/serial device in itself, the I/O Controller will decode 8 independent select control lines with data bus access via a bi-directional buffer. Buffered read and write lines are also available, thus establishing CPU protocol during I/O time.

It is intended that the controller be used with latch modules, serial interfaces and speech/sound generators which will be available from Maplin, designed as an expandable system to extend the Spectrum's capabilities. Of course, many other commercial add-on's could be controlled by this module, especially in the field of Robotics.

## Circuit Description

The Z80 CPU IN/OUT accumulator instruction determines the state of the lower (A0 - A7) address bus. This effectively allows 256 input/output ports for use either from the keyboard or with machine code. Spectrum firmware uses A0 to A4 for printer, key scanning, cassette and sound functions leaving A5 to A7 free for use with suitably decoded

address lines. IC1 determines when firmware is active and prevents the address decoder IC2 from being accessed. Assuming that a valid I/O Port address is presented, say 31, then the enable input of IC2 (pin 5) is taken low when A0 to A4 is logic high.

A5, 6 and 7 will be logic low, whereupon IC2 IORQ pin 4 is enabled and the decoded output appears on pin 15. There are eight select outputs (CS) from IC2, but only one may be accessed at any time. Address lines A5 to A7 determine which one of these CS outputs are active and Table 1 shows each I/O address associated with their respective control lines.

Select Line (CS)	Port I/O Address
1	31
2	63
3	95
4	127
5	159
6	191
7	223
8	255

Table 1

IC3 buffers the eight CS lines and produces an active low output. Alternatively, these outputs could all be made active logic high by fitting an inverting 74LS240 in place of IC3. A bi-directional data buffer, IC5, connects the Spectrum data bus to the port outputs for reading (PRD) and writing (PWR) operations. The PRD control line will not be active (logic 0) during the PWR sequence. Therefore, the data bus state always appears on the outputs of IC5 irrespective of correct port addresses being available or not! To read information in from the port, both IORQ and one of the eight CS lines must be active. IC4a OR's both of the enable signals producing a logic 0 to send to IC4b. When a logic 0 read signal is presented, IC5 switches the port data bus through to the Spectrum bus. This arrangement ensures isolation between the CPU and the outside world. The regulator, REG1, supplies the +5V for powering port electronics and is tapped into the Spectrum 9V PSU. Although a +5V regulated output has been brought out to the expansion connector, the current available is small. Additional loading of the internal regulator will increase heatsink temperature — and may cause overheating problems — especially on 48K machines with Interface 1 attached.

Facilities for connecting an external PSU have been added which connect to the IDC outlet for powering modules connected to the port. R9, D1 can be used as a power on/off sensing device and control to these devices – more on this later. Finally, the system RESET line is extended through so that the Spectrum can be externally reset, and/or peripherals reset during power up. The reset line is active low, and reset occurs after a low to high transition has been initiated.

## Construction

Begin construction by first fitting the 2 x 28 way Edge Connector into the PCB, (Figure 5). Insert the terminal pins from the track side, and *not* the legended component side. You will see a blank locating peg fitted in position 5 of the connector; line it up with the PCB so that it sits directly behind but on the opposite side to the bar on the legend. Do not cut off any of the connector pins as they are used for mounting an expansion PCB, as we shall see shortly. Carefully push every terminal pin through the PCB leaving a 4mm gap between the rear of the connector and the PCB. This allows for clearance when fitting the module into a box, otherwise not enough of the socket protrudes for insertion into the Spectrum. Make sure that both the PCB and the socket are at right angles to one another with an even 4mm gap along the back and solder all terminal pins to the PCB, on the component side! Each drilled hole has plated through connections joining the tracks on both sides of the board so it is only necessary to solder one side. Ensure the connector does not move whilst doing this as it can be quite difficult to straighten out afterwards.

## Expansion PCB

The smaller expansion PCB can be fitted at this stage although it is not part of the port section. All address, data, control and supply lines found on the Spectrum connector are extended out with this board. Note that no buffering or port outputs are available from here, just direct connections. Figure 5 shows all relevant details. In position 5 on both edges of this PCB, there are slots cut for alignment purposes. Insert the PCB between both rows of connector pins standing out from the main PCB with the slot against the legend bar. Gently bend all 54 terminal pins towards the expansion PCB until it is self supporting at right angles to the main PCB and solder each pin to the relevant track. Clean off surplus flux with brush and thinners and inspect every solder joint made so far. There must not be any short circuits between tracks or terminals; otherwise damage may occur to the Spectrum when running the port! As an extra precaution, use an ohmeter or multimeter set to measure resistance and test for shorts between adjacent tracks across and between both sides of the expansion PCB. A little time spent carefully checking at this stage is likely to prevent major headaches later on.

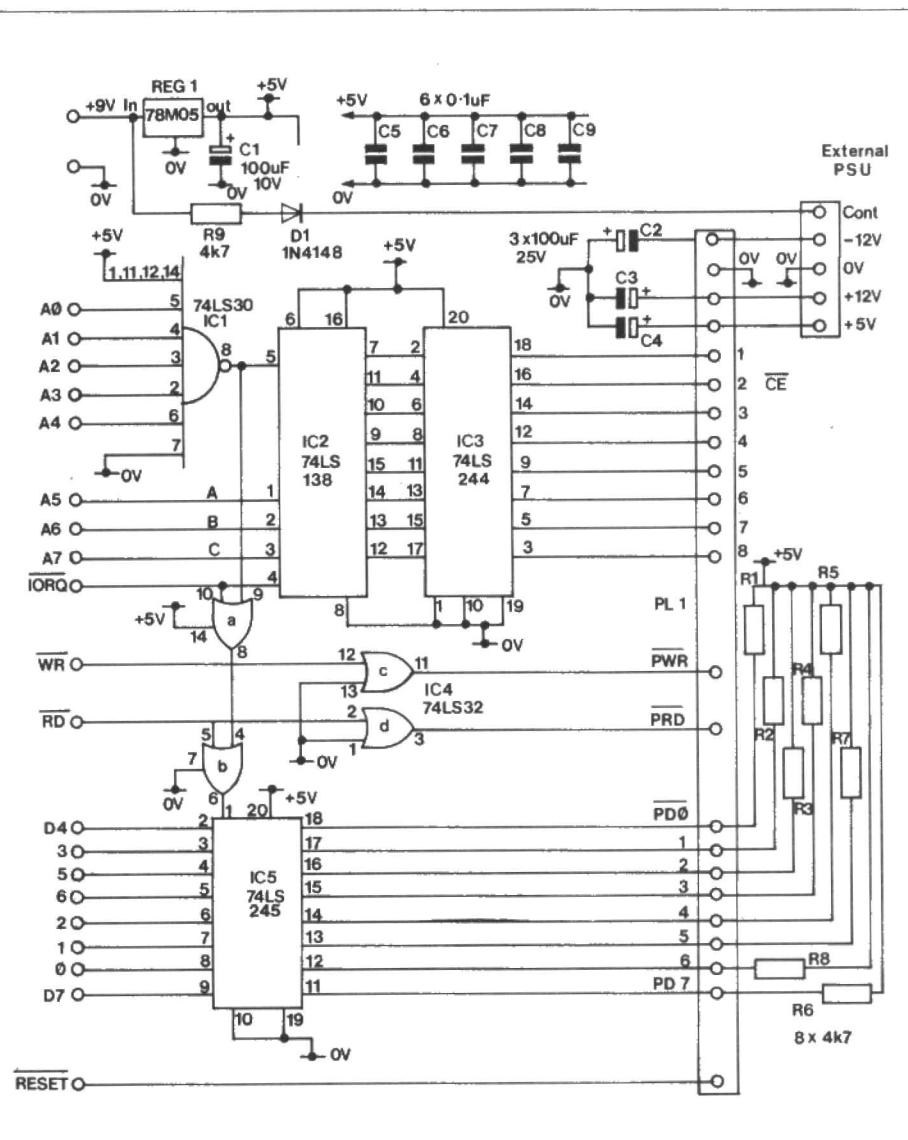


Figure 1. Circuit Diagram

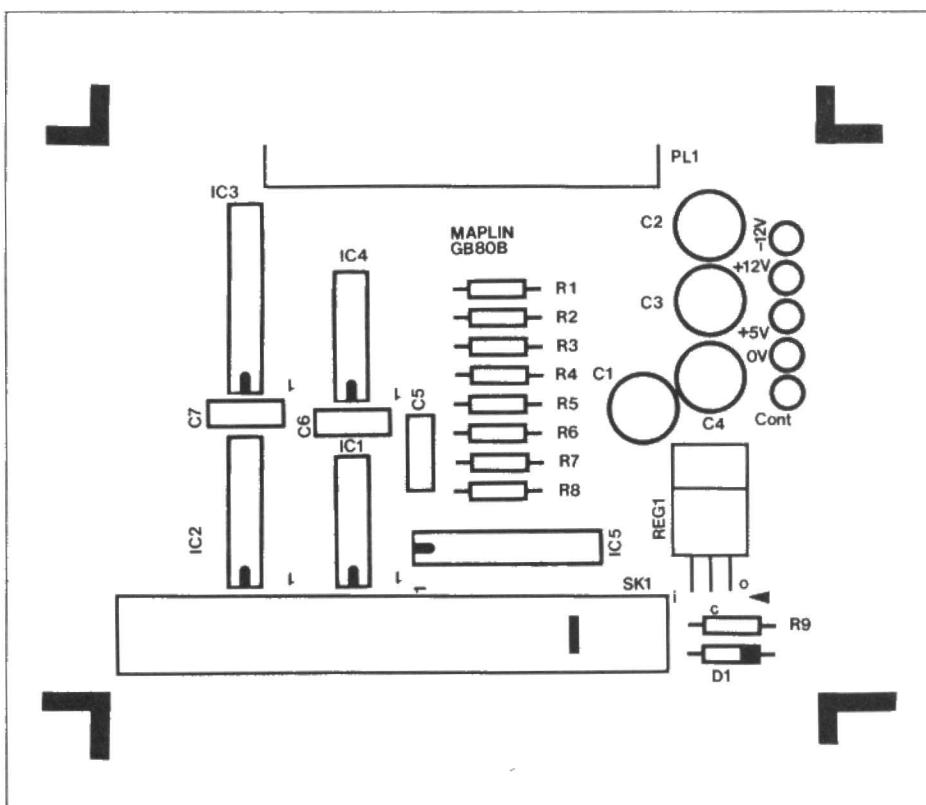


Figure 2. PCB Overlay

## **Component Assembly**

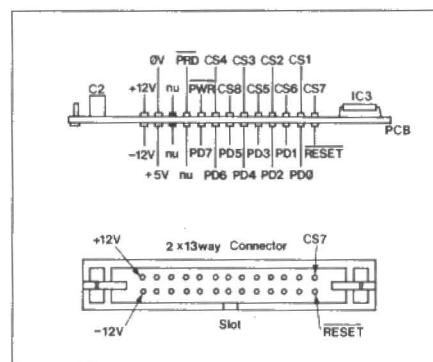
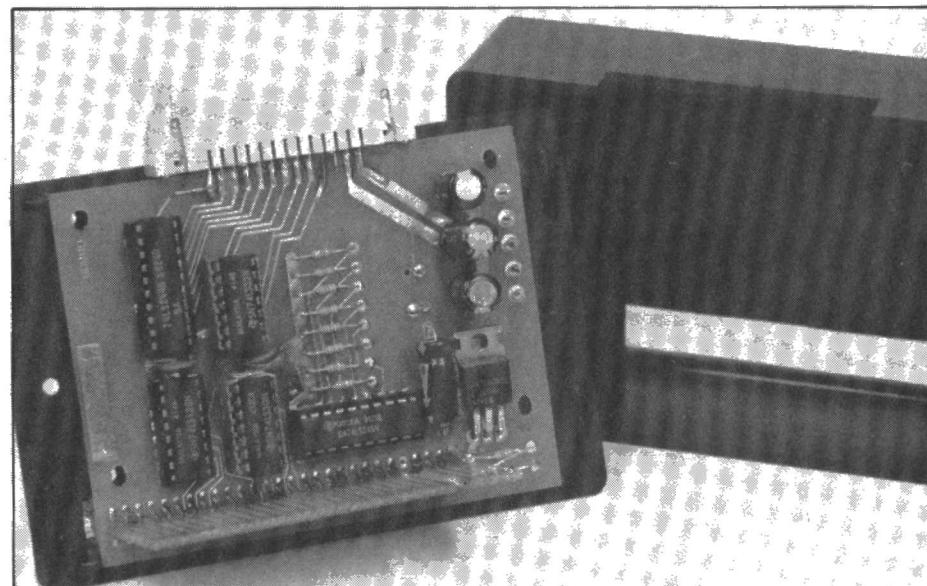
With reference to the Parts List and Figure 2, insert all five IC holders, noting that those for IC's 1 and 4 are 16 pin types, IC's 3 and 5 are 20 pin and IC2 is a 14 pin type. Push them down onto the PCB, then carefully solder each terminal in place. Mount C5, 6 and 7, which are circular disc capacitors, ensuring clearance between leads and nearby tracks. Next insert resistors R1 to R9. They are all of the same value and colour coded: Yellow, Violet, Red ('normal' code), or Yellow, Violet, Black, Brown (5 band code). Fit diode D1 which must be the correct way around with the Cathode (K) or ringed end pointing to the outside edge of the PCB. Align the band with the legend. Now insert capacitors C1, 2, 3 and 4. These electrolytic type capacitors are polarised and must only be fitted one way around. The case or negative end is designated with a -V sign on the package, or by the shortest of two leads. Unmarked or longest leads are then +V; insert according to the legend. Finally, the 3-pin regulator REG1 can be fitted with the flat side containing the heatsink bracket laying over a section of track on the PCB. Bend all 3 terminals downward, approximately 6mm away from the plastic body and locate each one through its mounting hole. This square of copper track beneath the regulator helps to dissipate heat radiated from the heatsink, although it is fairly insignificant. Solder remaining components in place, remove excess leads, wires etc, and clean track face with brush and thinners. Because plated through holes have been incorporated, it is possible for solder to run down to the component side of the PCB. Therefore, closely inspect both sides of the board, looking for short circuits and probable errors.

IDC Header

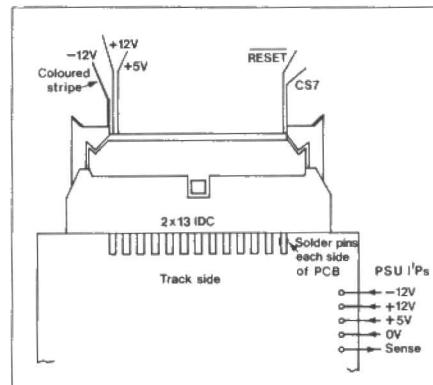
Every connection to and from the port is made via a 26-way IDC header plug. To fit this plug, slot the terminal pins over the PCB solder pads situated along the top edge, according to the diagrams of Figures 3 and 4. Arrange all terminals centrally to each pad and push the plastic body down onto the board edge. One side of the plug has a locating slot cut down it — arrange this facing outwards — which is situated on the track side of the PCB (same side as the 28-way socket!). Solder in place. It does not matter which side the slot faces, but Figure 4 notation is arranged for this particular configuration, so best stay with this standard.

## **Final Assembly**

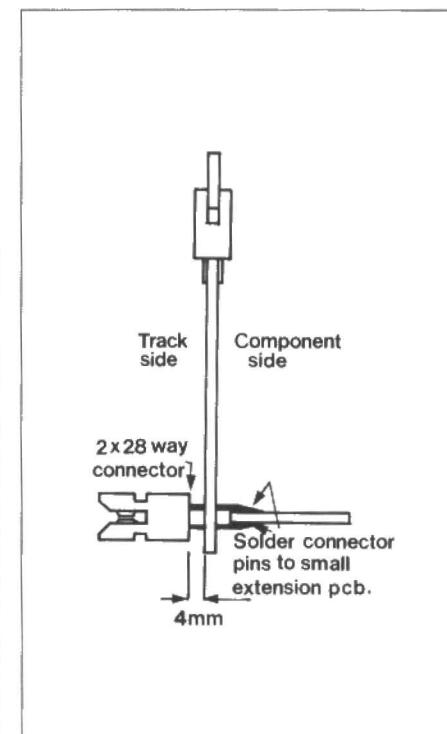
Insert IC's into their sockets. Looking from the front of an IC with the 'D' slot facing left, pin 1 will be the first pin beneath the slot. Be careful to observe this! Fit the 5 Vero pins by inserting them from the track side and gently push their heads down onto the track pad before soldering in position. Again, re-check all work done and when satisfied that all is well, proceed with testing the module.



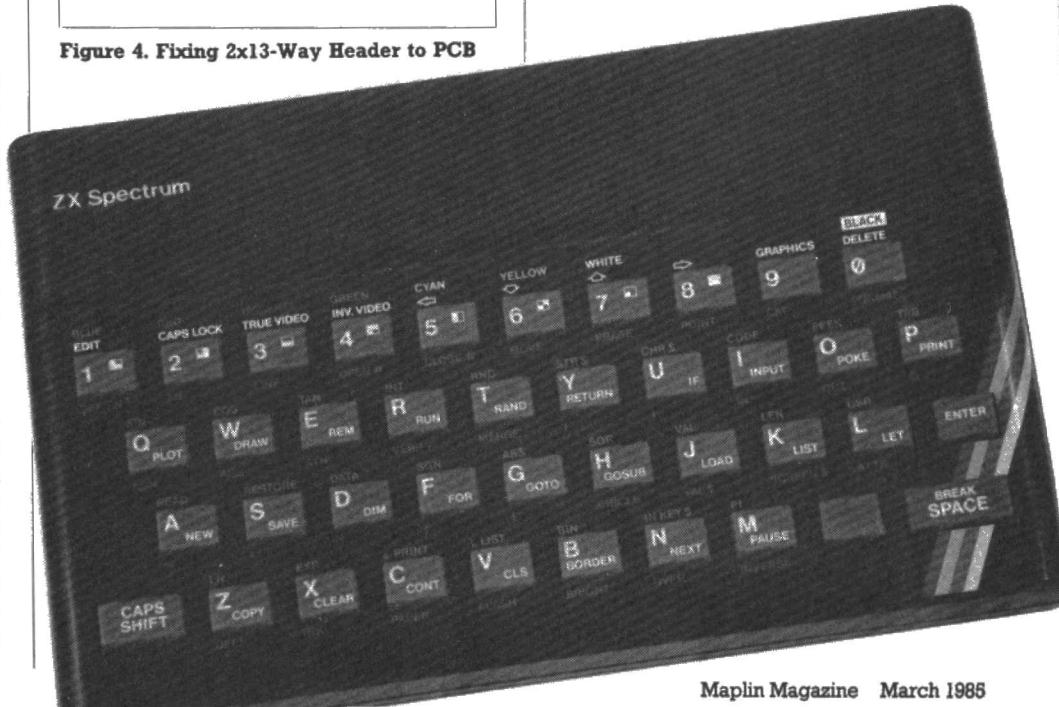
**Figure 3. Connections to Header Plug**



**Figure 4.** Fixing 2x13-Way Header to PCB



**Figure 5. Fixing 2x28-Way Edge Connector**



## Testing the Module

Refer to Figures 3, 4 and 8 for testing. You will again need the services of a good multimeter, a length of hook-up wire and a diode, which should be left over after construction.

Solder two short lengths of wire to each end of the diode as in figure 8 and strip, then tin the opposite ends.

With PSU disconnected, plug the I/O controller module into the Spectrum expansion port. Turn on the power and check the usual start-up routine and cursor appears. Now try all keyboard operations and make sure they function normally; if not, switch off immediately and remove the module. In this case, take out all IC's and re-insert the module – repeat the same check as before. The most common cause of problems is usually due to incorrect assembly and soldering, so if the Spectrum functions O.K. with the IC's out, then one or more of them may be suspect.

Set the multimeter to read 5V DC and connect with the negative lead attached to the heatsink of REG1 (OV) and positive lead to REG1 output pin, marked with an arrow. Expect a reading of +4.9 to +5.1V on the supply rail. Remove the meter.

Type in PROGRAM 1 and RUN it.

Each 1 of 8 ports will be addressed and the DATA bus read. The left hand column lists each port and the right hand shows the data read which, for this test, should be &H FF (255) for every port address.

ENTER NEW and type in  
PROGRAM 2.

RUN this program, input address 223 and data received will be displayed as zero, in the right hand column opposite. Take the test diode and connect the cathode (K) to CS7 – port address 223 – and the anode (A) to PD0. Figure 3 details the appropriate IDC terminals. A new data reading of 1 should be displayed, due to the CS7 select line going low and pulling data line PD0 low with it. In fact, the data is inverted and is really 254 as

### PROGRAM 1

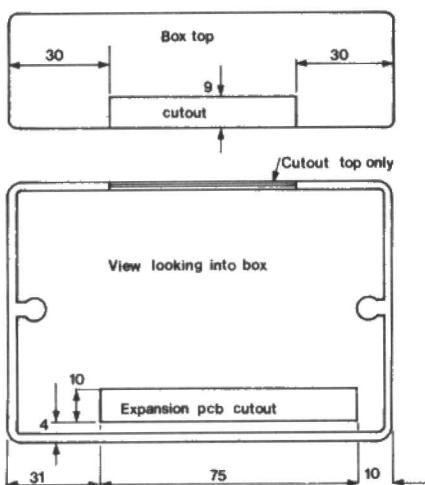
```
10 FOR I=31 TO 255 STEP 32
20 PRINT I,IN I
30 NEXT I
```

### PROGRAM 2

```
10 CLS:RESTORE 200
20 PRINT "ADDRESS";
30 PRINT TAB 10;"SELECT(CS)";
40 PRINT TAB 23;"DATA":PRINT
50 FOR I=1 TO 8:READ a,cs
60 PRINT TAB 2;a;
70 PRINT TAB 15;cs;
80 PRINT TAB 21;"*****"
90 PRINT:NEXT I
100 INPUT "ENTER ADDRESS";p
110 RESTORE 200
120 FOR J=1 TO 8:READ a,cs
130 IF p=a THEN GOTO 150
140 NEXT J:GOTO 100
150 IF INKEY$<>"" THEN GOTO 150
160 PRINT AT 21,0;"PRESS ENTER TO CHANGE ADDRESS"
170 PRINT AT INT(P/16)+1,23;255-IN P;"**"
180 IF INKEY$=CHR$ 13 THEN GOTO 10
190 GOTO 170
200 DATA 31.1.63.2.95.3.127.4.159.5.191.6.223.7.255.8
```

### PROGRAM 3

```
10 CLS
20 FOR J=31 TO 255 STEP 32
30 FOR I=0 TO 255
40 PRINT AT 5,7;"PORT =";J
50 PRINT "DATA =";I
60 OUT J,I
70 PAUSE 10
80 NEXT I:CLS
90 NEXT J:PRINT "END"
```



[a] Dimensions in mm  
[b] 'A' holes Ø3mm csk.on outside of lid to suit pcb fixing screws.

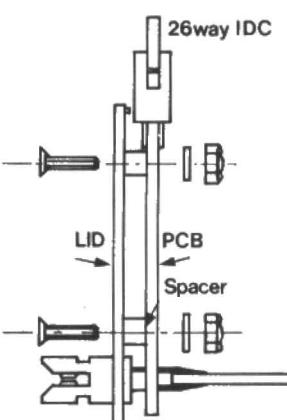
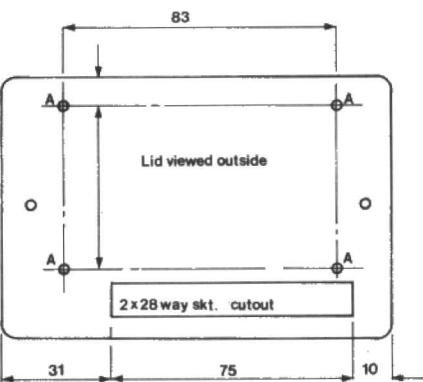


Figure 6. Box Cutting Details

March 1985 Maplin Magazine

Figure 7. Fixing PCB into Box

PD1 to PD7 are all pulled high by resistors R1 – R8, thus returning 255 – 1. Line 170 in the program inverts data readings for clarity during testing. Removing the test diode from PD0 will cause data to return to 0. Repeat this test on the remaining seven data lines PD1 to PD7 using CS7 only, checking for data 2, 4, 8, 16, 32, 64 and 128. All combinations from 0 to 255 can be found by joining different data lines together and connecting to CS7 as required. Press ENTER and input a new port address from the list. Again repeat previous tests with the test diode connected to the selected CS pin until all eight addresses and CS lines have been checked. Only data input to the port is read in while running program 2 and a good indication of correct operation results in doing this. However, data output should also be checked but this operation is not quite as easy. To test port WRITE requires additional hardware in the form of latching registers and LED's, and figure 9 shows a suitable circuit of this type. Data placed at the 74LS374 inputs is clocked into the latch during the WRITE cycle and appears at the Q outputs. Sending out data codes 0 – 255 will bring on the appropriate combination of LED'S at this time but not during the read cycle. PROGRAM 3 can be used with Figure 9, with c.c.t connected to the I/O module where each port and data code will be set up.

## External PSU

As mentioned before, external power source connections can be brought into the I/O PCB and hence to the IDC plug. Note that these supplies do not drive the module at all. +12V, -12V, +5V and 0V inputs are available which can be extended to peripheral devices along the IDC cable and connector. Also Figure 10 shows a simple application for disabling or enabling these power rail connections when turning the Spectrum off or on – this being useful for preventing false triggering or even damage from occurring.

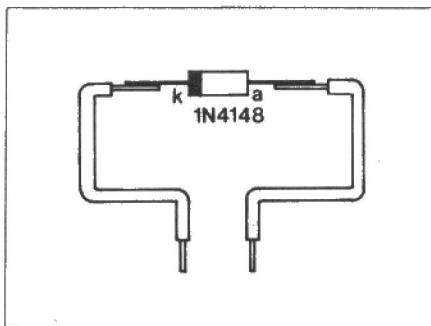


Figure 8. Test Diode

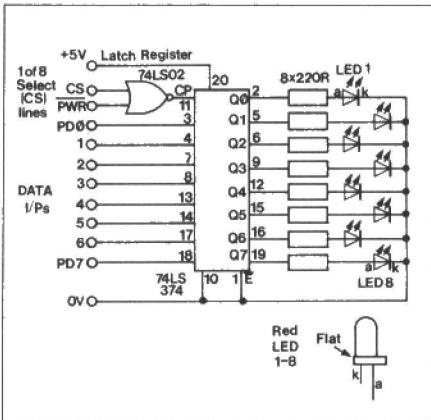


Figure 9. Additional Circuit to Test WRITE Function

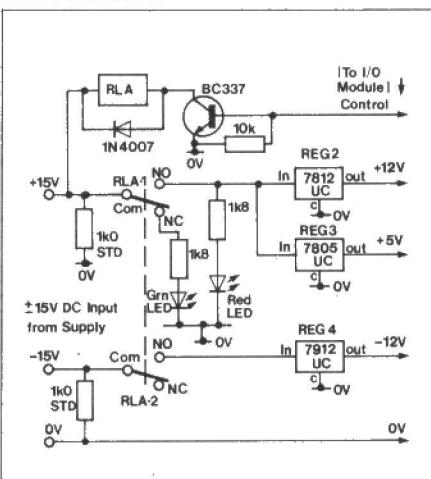


Figure 10. Circuit For External PSU

## Further Expansion

Additional modules designed to be used with the controller module will be available, such as a parallel/serial system for communications applications; a sound/speech generator with amplifier and speaker and a 4-channel PWM servo/motor drive module. Some of these projects can be found in this issue and others will appear in future editions.

## Interface 1

The I/O module should function normally with Interface 1 although this cannot be guaranteed in every case. We have found that some series 3/3B 48K machines do not tolerate extra 'add on's' especially when the ZX printer is attached, possibly due to excessive loading on the PSU.

## Fitting into a case

Should it be required to enclose the module, and it is highly recommended this be done, Figures 6 and 7 give the necessary cutting and drilling details for the box. There are 3 cut-outs to be made and 4 holes to be drilled in the lid for mounting the PCB. Use 4 1/8in 6BA spacers, bolts and nuts for this purpose. Fitting a 5-pin DIN plug into the box sidewall will allow a neat connection for an external PSU, if required, or perhaps a larger box could be used for containing both the PSU and the I/O module.

## Final Hints

Control lines CS1 – 8, PRD and PWR are all active low (0V). Use CS to select the peripheral device and PRD/PWR to enable Tri-state buffers on the data bus. Remember to connect the common 0V line as well! Only the addresses in TABLE 1 are decoded so if you are using several different modules as well as this module, check what codes can be used without clashing with any others.

## SPECTRUM I/O CONTROLLER PARTS LIST

RESISTORS: All 0.4W 1% Metal Film

R1-9 4k7

### CAPACITORS

C1	100 $\mu$ F 10V Axial Electrolytic
C2,3,4	100 $\mu$ F 25V P.C.Electrolytic
C5,6,7	100nF Minidisc

### SEMICONDUCTORS

D1,Test	IN4148
IC1	74LS30
IC2	74LS138
IC3	74LS244
IC4	74LS32
IC5	74LS245
REG 1	$\mu$ A78M06UC

### MISCELLANEOUS

PL1	26-Way IDC Header	1	(FJ15R)
SK1	2 x 28-Way Edge Connector	1	(FC23A)
14-pin DIL Skt		2	(BL18U)
16-pin DIL Skt		1	(BL19V)
20-pin DIL Skt		2	(HO77I)
Veropin 2141		1 pkt	(FL21X)
Spectrum I/O Controller PCB		1	(GB80B)
Spectrum I/O Pin Ext PCB		1	(GB81C)
8BA C/S Screws x 1/4in		1 pkt	(LR00A)
8BA Nut		1 pkt	(BF19V)
8BA x 1/4in Spacer		1 pkt	(LR69A)
Box PB1 Black		1	(LH14Q)

A kit of the above parts is available.

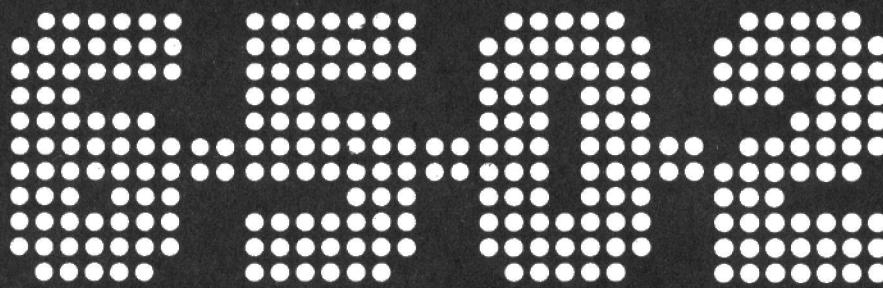
Order As LK65V (Spcrm I/O Cntrlr Kt) Price £17.95

The following are also available separately, but do not appear in the 1985 catalogue:

Spectrum I/O Controller PCB Order As GB80B Price £5.75

Spectrum Pin Extension PCB Order As GB81C Price £1.85

# THE MACHINE CODE PROGRAMMING WITH THE



By Graham Dixey, C.Eng., M.I.E.R.E. Part Seven

## The Stack

The 'stack' is an area of random access memory reserved, in the most general terms, for the temporary storage of data. Therefore, it is bad practice, though quite possible to do so, to encroach on it for user programs. One of the most powerful features of microprocessor-controlled systems is the ability to transfer control at given instants of time. Examples of this have already been given in this series. For example, it was shown that it is possible to run a program and, apparently at the same time, supply data to a peripheral (such as a printer). This is done by allowing the peripheral to 'interrupt' the current program when it needs attention.

It doesn't need much thought to appreciate that such interrupts may occur at inconvenient moments in time, i.e. when the processor is manipulating data, when the X and/or Y registers are holding specific values of data (such as in a counting-up or counting-down sequence), when the Processor Status Register is being used in a loop, and so on. It is necessary to ensure that the condition of all relevant registers, ports and memory locations is exactly the same after an interrupt as before it. Thus the function of the stack is to hold all such data during an operation such as an interrupt service routine and then to restore the status quo on its completion. The act of placing data onto the stack is called 'pushing', while the process of retrieving data from the stack is termed 'pulling' or 'popping'.

The stack operates in a particular way, known as the Last In First Out (L.I.F.O.) principle. Data access is entirely sequential, starting at the 'top' of the stack (i.e. the highest stack address), with each new byte of data being placed after the last one, and reversing the process to remove data. There is no way of getting at a byte of data without first removing the data bytes before it. This may sound like a limitation but in the usual context it isn't.

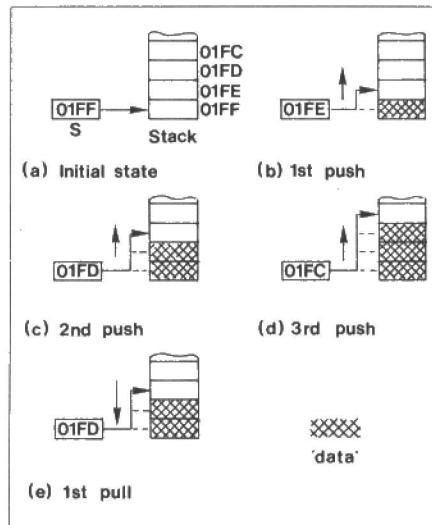


Figure 1. Pushing and pulling the stack

Associated with the stack is a register known as the Stack Pointer (S). Its function is to keep track of how far into the stack the data has been pushed. It actually points at the next free location. Figure 1 shows the contents of the Stack Pointer after three successive pushes and one pull, in a 6502 system. Notice how the stack 'grows upwards' during the pushing operations; also how the Stack Pointer register is decremented at each successive push. When data is pulled from the stack the reverse occurs. The last data byte entered is withdrawn and the Stack Pointer is incremented. Considering that the area of RAM reserved for the stack is a whole 'page', i.e. 256 locations, each capable of holding a data byte, it is reasonable to ask why so much space is devoted to this function, particularly when we appreciate, as we shall soon, that only the contents of the Program Counter, Accumulator and Processor Status Register can be pushed onto the stack anyway.

Well there may be several reasons for this. For instance the desire for orderliness, compartmentalising the stack into one specific page of memory.

There may also be occasions when, in a limited memory system, an area of RAM on, say, page 0 needs to be temporarily cleared (but not lost) in order to provide data space during an interrupt routine. Thus, a block transfer of data can be made into the stack. Again, if many sub-routines are 'nested', their return addresses will be held in the stack, which obviously must have adequate capacity.

Since there is no separate instruction for pushing or pulling data in the X and Y registers, input/output ports, or memory locations, all transfers will have to be effected by loading into the Accumulator and pushing this. Pulling is achieved by popping the stack contents into the Accumulator, following this with a store instruction to the appropriate location - see Table A. Notice how the LIFO protocol is observed by the order in which memory locations MEM1 and MEM2 are pushed and pulled.

	LDA	MEM1
Pushing from memory to stack.	PHA	
	LDA	MEM2
	PHA	
	"	
	"	
	"	
	"	
Pulling from stack to memory.	PLA	
	STA	MEM2
	PLA	
	STA	MEM1

Table A

## The Stack and Sub-routine CALLS

Unless a program is a very simple one it is bound to contain a number of sub-routines. Indeed very complex programs consist mainly of a variety of sub-routines, some nested within others. When a point is reached in a program at which a sub-routine is required, a sub-routine CALL is said to be made. This

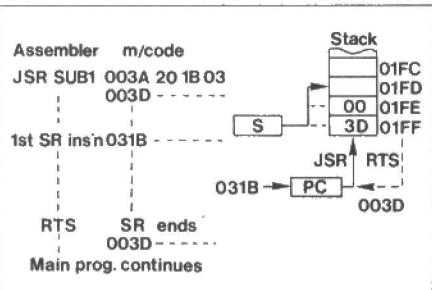


Figure 2. The stack during sub-routine calls

is, in effect, a software interrupt and requires that the contents of the PC, at least, must be saved so that the main program may resume at the correct place after the sub-routine has been completed. Thus, the stack will always be used at a sub-routine call.

The instruction that initiates such a call is JSR and it is automatic that on encountering this instruction, the PC contents +2 will be pushed onto the stack. The process is reversed at the end of the sub-routine when the RTS instruction is found and the PC contents are restored. The Stack Pointer contents are automatically adjusted in both cases. This is illustrated by Figure 2.

A program on page 0 encounters a sub-routine call at location 003A. The op-code for JSR is 20, which is Absolute addressing mode only and so requires a two-byte operand. Assuming the sub-routine SUB1 starts at location 031B, this operand, low byte first, is 1B03. However, at this instant the PC holds the address 003D, for the next main program instruction, and this is pushed, low byte first, onto the stack. Assuming that the stack was initially empty, S first held 01FF (first free stack address) but, after these two pushes, now holds 01FD. The PC is loaded with the sub-routine start address 031B and the sub-routine runs. At the end of the sub-routine, RTS causes the PC contents to be pulled from the stack and the main program continues.

## Stack Instructions

Obviously the JSR and RTS instructions cause automatic stack operation. Two other stack instructions, PHA and PLA were introduced earlier, giving the programmer the freedom to push and pull the Accumulator contents. There are two others, PHP and PLP that enable the Processor Status Register to

TXA	Transfer X into A.
PHA	Push A.
TYA	Transfer Y into A.
PHA	Push A.
"	
"	
"	
PLA	Pull A.
TAY	Transfer A into Y.
PLA	Pull A.
TAX	Transfer A into X.

Table B

be treated similarly. This makes a total of four instructions, each of which uses Implied addressing mode, i.e. no operand is required.

It should be obvious that to save the X and Y register contents, use must be made of the PHA instruction, followed eventually by PLA to restore them. It is necessary to transfer the X (or Y) register contents to the Accumulator and back again using the 'transfer' instructions TXA, TYA, TAX, TAY. Thus, in Assembler, the pushing and pulling of the X and Y registers is shown in Table B.

When sub-routines are 'nested', one resides within another and perhaps another resides within that one and so on. This is referred to as the 'levels' of sub-routine calls. This is where the LIFO structure of the stack plays a vital role in saving and restoring the return points at each level of call. Figure 3 should make this clear for a case of sub-routines nested to three levels.

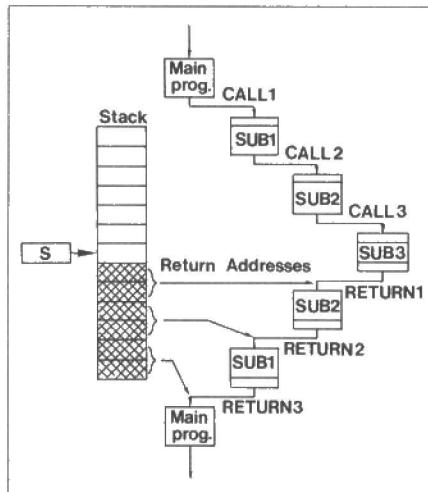


Figure 3. The stack and nested sub-routines

## Passing Parameters

Generally the object of a sub-routine is to operate on some data which has, therefore, to be made available. Such data is referred to as the 'parameters for the sub-routine' and has to be passed to the sub-routine in some way. An obvious way is to have these parameters available in memory locations so that a program line in the sub-routine would read something like LDA P1, where P1 is the memory location holding the data. This seems alright, but suffers from the drawback that this memory location (and any others similarly used for data storage) are embedded in the sub-routine. Since a sub-routine is supposed to be a general tool, available for a variety of programs, this can make life awkward for the programmer, having always to keep an eye on specific locations. Sub-routines of this sort are for addition, multiplication, square-roots, etc.

If only two parameters were required, these could be placed in the X and Y registers, should these be available. The program is then independent of memory addresses and is truly general in nature. A further

alternative that is also independent of memory is to push the data onto the stack and allow the sub-routine to pull it for its use.

## Interrupts

As we know, an interrupt is a way in which a peripheral can tell the processor that it requires attention, either to send or receive data. Usually a change of level, e.g. from logic 1 to logic 0 is effected at a special pin on the 6502. Actually the 6502 has two such pins, known as NMI and IRQ, standing for Non-maskable Interrupt and Interrupt Request respectively, either of which may be taken low to initiate an interrupt. The difference is that IRQ can be disabled by setting the Interrupt Mask bit in the Processor Status Register; NMI cannot be disabled.

On receipt of an interrupt request from a peripheral, the processor completes its current instruction and then pushes both PC and P contents onto the stack. It also sets the Interrupt Mask bit just mentioned so as to inhibit further interrupts of the same or lower priority. It then goes to a pair of memory locations to find the start address for the Interrupt Service Routine and loads this address into the PC. In 6502 manuals the locations are usually stated as follows:

FFFF and FFFF: NMI vector.  
FFFE and FFFF: IRQ vector.

However, at least one machine is known in which the vectors are found elsewhere in memory so be warned! It is the responsibility of the programmer to load the interrupt vectors into these locations.

The Interrupt Service Routine (ISR) is just a special sub-routine to service the particular peripheral. The last instruction in this routine will be RTI, which performs a similar function to the RTS at the end of other sub-routines. That is, the original contents of PC and P will be pulled from the stack to allow the main program to continue from where it left off. If it had been necessary to push the contents of any other registers or memory locations, this would have been done, by methods already explained, at the start of the ISR, the pulling being done immediately prior to the RTI instruction. Another important instruction that should be included just prior to RTI is the CLI instruction, to clear the Interrupt Mask bit. Failure to do this will mask off any further calls on IRQ. Figure 4 shows how the stack might look after a typical interrupt.

## Multiple Interrupts

Of the two 6502 interrupt lines, IRQ is the general purpose line and NMI is often

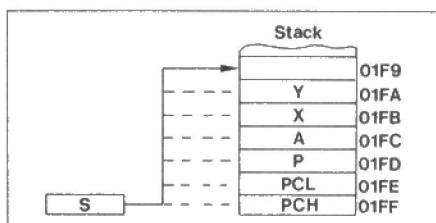


Figure 4. The stack after an interrupt

reserved, since it has the higher priority, for alarm situations such as loss of power. This means that if several peripherals are to be serviced by the processor, they must share a common interrupt line, namely IRQ. This obviously raises several questions.

- How is it known which peripheral wants attention?
- How can the ISR relevant to the particular peripheral be found?

There are two approaches, a software one and a hardware one. The software method is known as 'polling' and consists of using a short program to test the status of a flag, on the peripheral which is connected to the input/output ports. Figure 5 shows the physical arrangement of a system servicing three peripherals.

The IRQ line is connected in the wired-OR configuration so that any peripheral can initiate an interrupt by taking it low. Each peripheral has its own Interrupt Enable Flag (IE Flag) which will be set (i.e. at logic 1) only when that particular peripheral requires attention. Each flag is connected to an I/O port line so that its status can be determined by the usual loading and masking operations in the Accumulator. Now consider the sequence of events when an interrupt occurs.

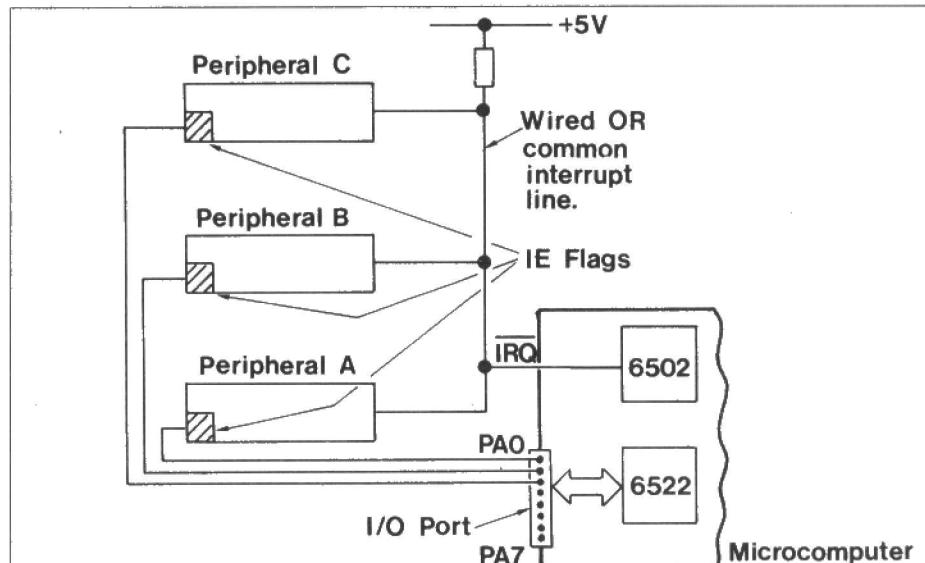
First when  $\overline{\text{IRQ}}$  goes low the 6502 will check the Interrupt flag in the P register. If it finds it enabled (clear) it will proceed with the interrupt by saving the PC and P registers on the stack and branching to FFFE and FFFF to find the interrupt vector. Assume this has been allocated to 0300. The PC will be loaded with 0300. What will be found at this address? In the case of a single peripheral it would simply be the ISR for that peripheral, which would then be executed. However, in this case it would find the polling program. This is shown in Table C in Assembly Code to show how it might appear (by now you should have a good idea of how to write your own). It is assumed that the Peripheral IE Flags are connected to Port A such that Peripheral A goes to PA0, Peripheral B goes to PA1 and Peripheral C goes to PA2.

**LDA DRA** Loads Port A data into Accumulator.

**AND #01** Tests bit 0 : if '1' found, **BNE ISRA** goes to Peripheral A ISR.  
**LDA DRA** Loads Accumulator again.  
**AND #02** Tests bit 1 : if '1' found, **BNE ISRB** goes to Peripheral B ISR.  
**LDA DRA** Loads Accumulator again.  
**AND #04** Tests bit 2 : if '1' found, **BNE ISRC** goes to Peripheral C ISR.

**Table C**

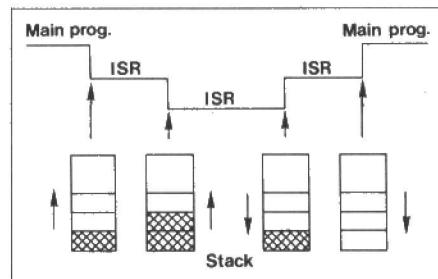
As you can see from Table C, this is a simple and repetitive program which just tests the inputs to the first three I/O lines of Port A and branches to one of three sub-routines on the result of a successful BNE test. There is no need to loop back since a '1' must be found at the first pass otherwise this routine wouldn't



**Figure 5. System using multiple interrupts**

have been called. Because the AND masking operation changes the Accumulator contents, it is necessary to reload this register before each new test.

The term 'polling' simply means a sequential interrogation and, in this case, should not be confused with a general polling method in which the peripherals' status flags are 'perpetually' checked by a looping polling program to see if any one is set, there being no interrupt in use. This latter method is time-wasting and inefficient. The method just discussed only calls the polling sub-routine after receipt of an interrupt signal. This allows the processor to concentrate on other matters for the rest of the time.



**Figure 6. The stack with multiple interrupts**

The hardware alternative naturally requires additional hardware in the form of a 'hardware arbitrator circuit'. This responds to an interrupt request by sending back an INTA (Interrupt Acknowledge) signal to each peripheral. Only the one that initiated the interrupt is able to respond, which it does by sending to the processor its ISR start address. Priority is established by 'daisy chaining' in which the INTA signal is sent to peripherals in order of their importance. This incidentally answers the question 'what happens when two peripherals interrupt simultaneously?' The higher priority one gets interrogated first and so gets serviced first. It is possible for peripherals to queue for attention and it is also possible for a low priority interrupt to be interrupted by a higher priority call. In this case the stack gets pushed by the first interrupt (to preserve P and PC for the main program) and then pushed

again by the second interrupt, to preserve P and PC for the first interrupt. The stack is successively pulled as first the second interrupt routine finishes and then the first interrupt routine is completed. Figure 6 shows this idea.

## The BRK Instruction

The BRK mnemonic stands for BREAK, as is probably quite obvious. It is included here because it is a form of software interrupt and has similar effects to a regular interrupt. It results in the pushing of PC and P onto the stack and a branch to FFFE, FFFF. It is a useful debugging aid since, by including it anywhere in a program, it is possible to create a 'breakpoint' and allow a branch to a sub-routine for program analysis. In order to know whether the program has been interrupted by a BRK command or by a regular interrupt, the B flag in the P register should be checked. If equal to '1' it was a break but if equal to '0' it was an interrupt. The program segment shown in Table D in assembler will perform this function.

<b>PLA</b>	Pull P register from stack.
<b>PHA</b>	Push P register back onto stack.
<b>AND #10</b>	Test B bit : is it '1'?
<b>BNE</b>	Branch to break sub-routine.

**Table D**

Don't make the mistake of thinking that the first and second lines of this routine cancel each other. The first line loads the Accumulator with the P register contents; the second line restores the status quo of the stack. The Accumulator still contains the pattern of bits from the P register, which can then be tested by the third and fourth lines.

This series on the 6502 is almost finished now. It is a fact that one could go on forever; there is always so much to learn about programming and the more one learns the more fascinating it becomes. However, the next part will be the last and those instructions not so far discussed will be explained then together with examples of their usage.

# TRUNDLE

## THE CHANNEL FOUR ROBOT

### Introduction

The Trundle package consists of an interface and memory expansion board for the ZX81 and the extra pieces necessary to make a ZX81 based 'Trundle' robot. The system is supplied in kit form with a comprehensive set of instructions.

The interface was designed with the aim of encouraging participation in robotics and allowing other applications of interfacing. This exciting field is often avoided by both software writers as being too complicated electronically and by electronics enthusiasts as being too complicated from the programming angle.

However, these fears are not justified. An interfacing project may be as hardware or software intensive as the designer wishes. A lack of skill in the hardware field can usually be made good with an extra piece of software and vice-

### The Inside Story By Eddie Forrester & Robin Moorshead

versa. Trundle was designed to bring the beginner up to a reasonable level of competence with both a computer keyboard and a soldering-iron.

The package itself breaks down into four main sections:-

- The Interface.
- The Memory Expansion.
- The Sensor Board.
- The Motor/Chassis Unit.

### The Interface

This provides eight input lines and eight output lines, the latter being buffered by relays to enable the direct control of small motors, buzzers etc. See Figure 1.

Data is latched onto the output lines by the command:

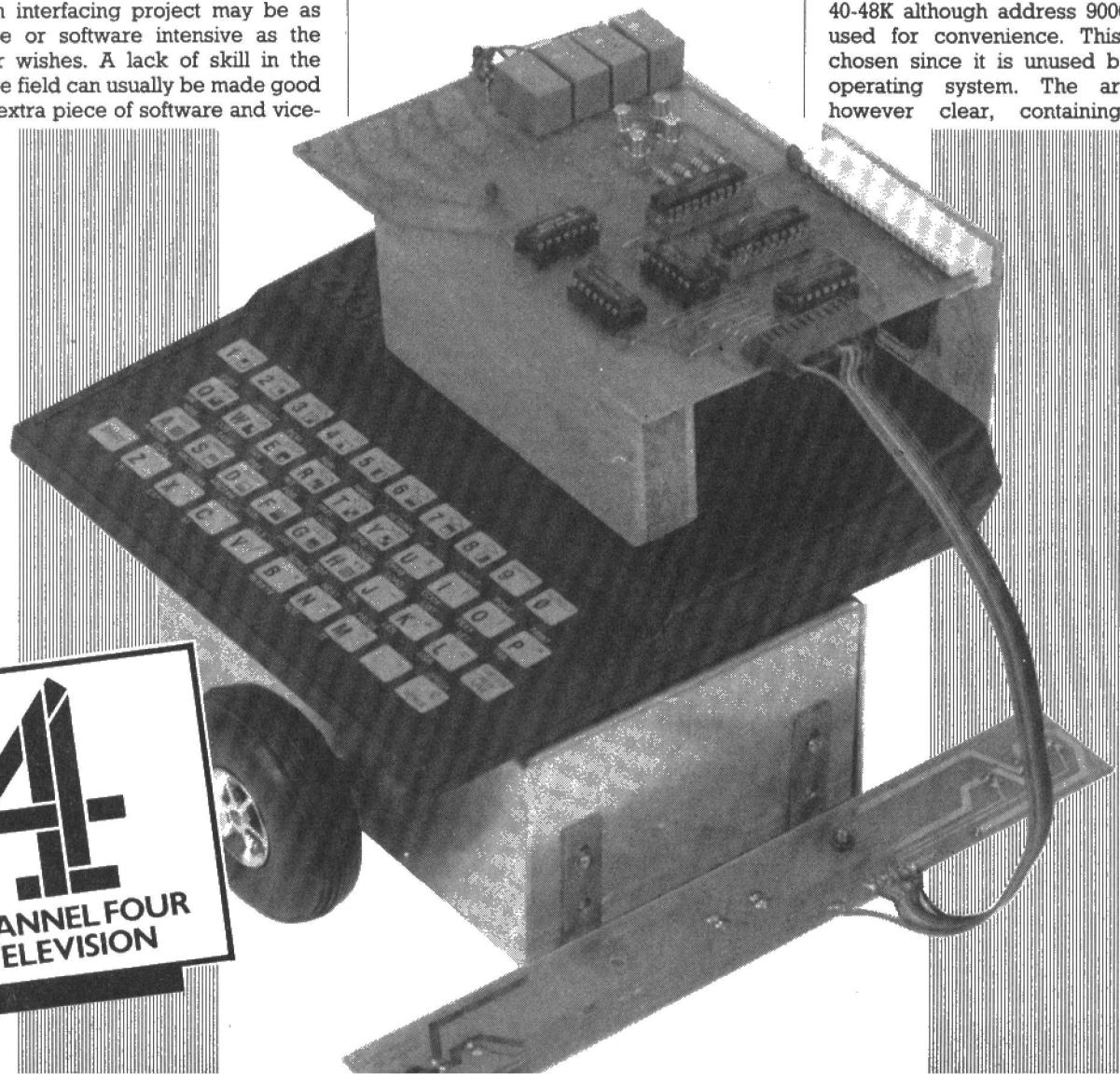
POKE 9000, data.

The data is presented on the output lines in its binary form, eg.

If data = 1 then only the relay for bit 1 is energised.

If data = 5 then the relays for bits 1 and 4 are energised.

The interface is memory mapped and may be addressed between 8-16K or 40-48K although address 9000 is usually used for convenience. This area was chosen since it is unused by the ZX81 operating system. The area is not however clear, containing a ROM



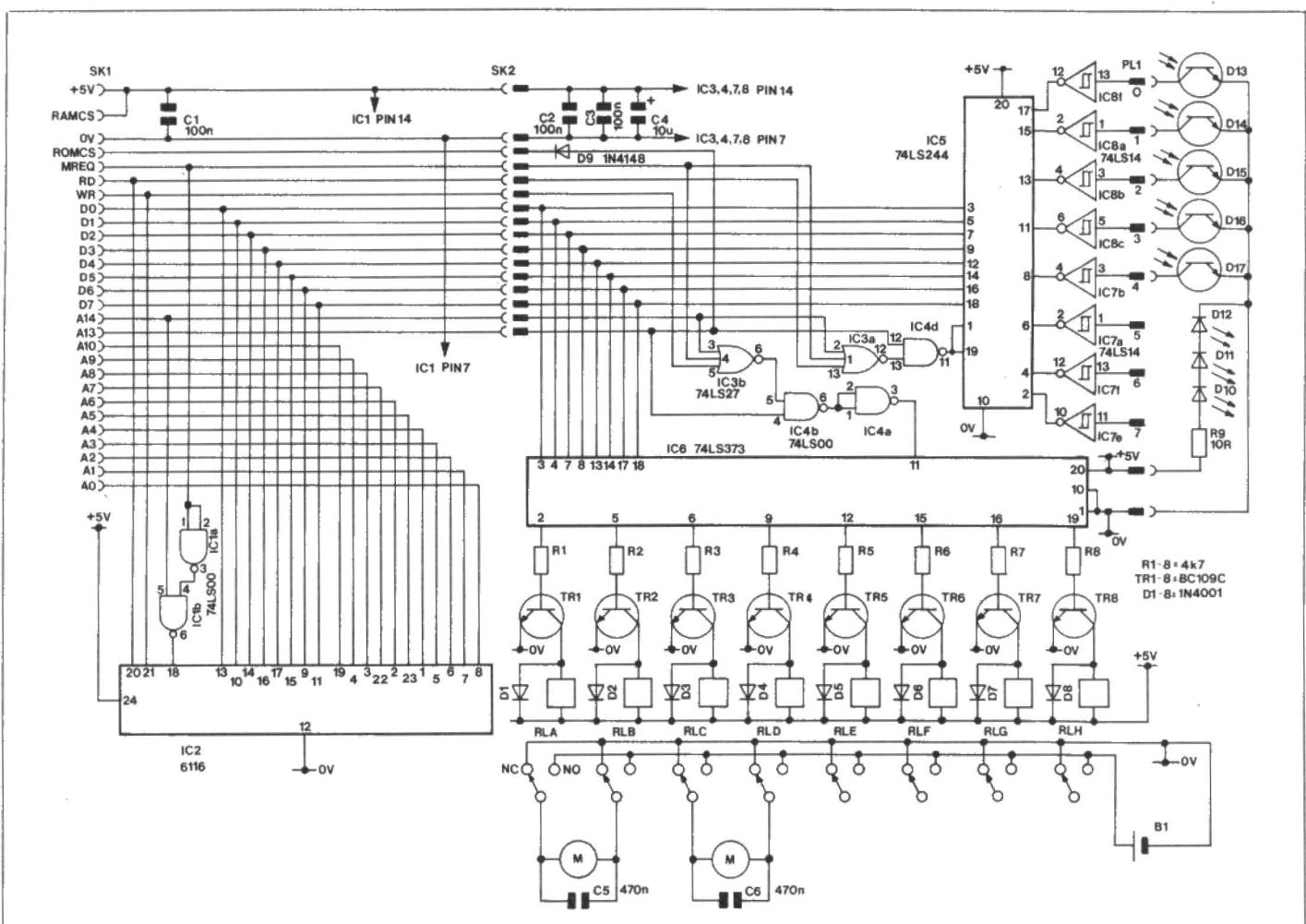


Figure 1. Trundle circuit diagram.

shadow. If this shadow were to be left, the operation of the interface would be corrupted. For this reason, ROMCS is connected to A13 through a diode D9 so that it is pulled high if any address containing A13 appears on the address bus (as at any address in the 8-16K ROM shadow). This disables the ROM when necessary without affecting the normal operation of the ZX81.

The output of IC3a will only go high if the computer is writing to memory (MREQ and WR low) in ROM or ROM shadow areas (A14 low). This signal is then 'ANDED' with A13 to ensure that the computer is not trying to communicate with ROM and this output (from IC4b) used to take the 'E' pin of IC6 high. This prepares IC6, an octal latch, for data transfer. When MREQ goes high again,

the 'E' pin is taken low, the new data being latched onto the output lines on the falling edge. These lines are then used to drive the relays through TR's 1 to 7. The diodes across the relay coils protect the transistors from the back EMF spikes that occur when the relays are de-energised.

The select circuitry for the input port is essentially the same as that for the output port differing only in that it

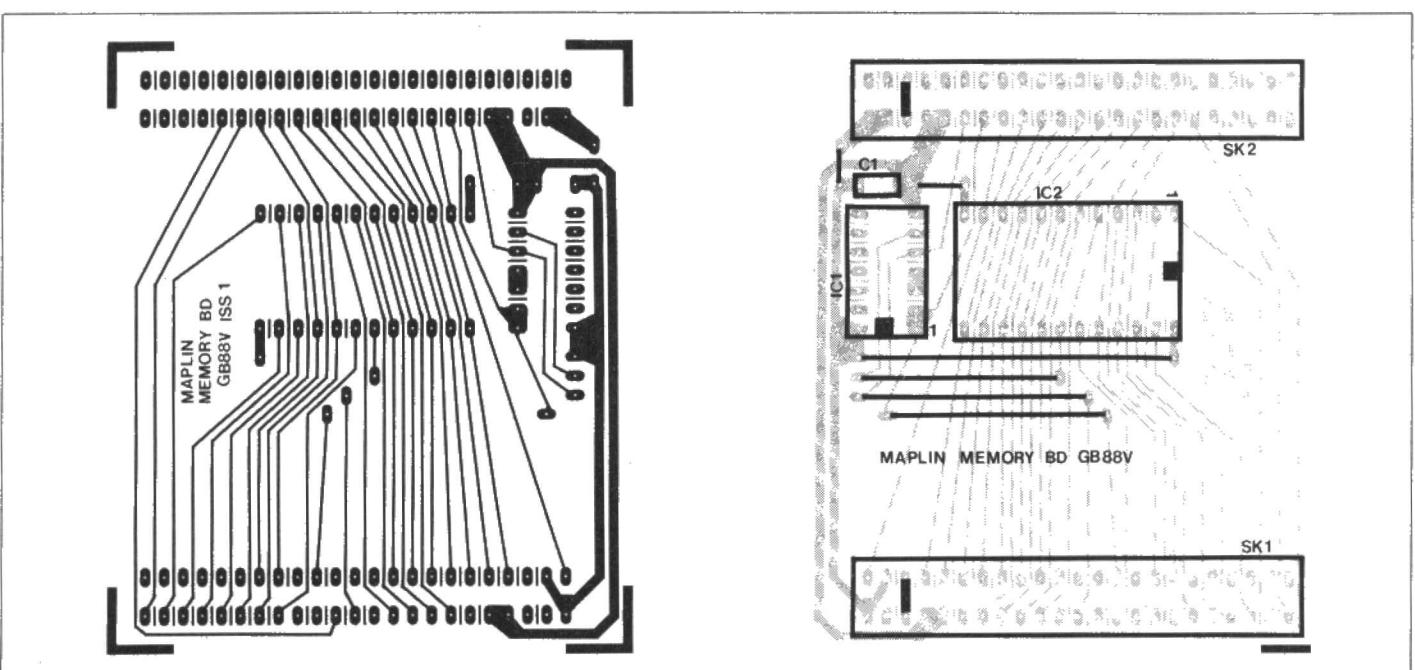


Figure 2. Memory PCB artwork and overlay.

provides an active LOW output when the computer wants to READ data. This output is used to enable IC5 (an octal buffer) which effectively connects the input lines directly to the ZX81's data bus.

IC's 7 and 8 are Schmitt inverters and serve to square up the input signal.

## The Memory Expansion

Although the standard 1K ZX81 does not provide enough memory for any but the simplest of interfacing programs, the extra cost and power consumption of a 16K RAM pack are not worth while. Instead, this package contains a CMOS

memory board which provides extra memory whilst actually lowering the power consumption of the ZX81. The memory board also serves to connect the ZX81 to the interface board.

IC2 is a 6116, 2K x 8 CMOS RAM. It is selected when both A14 and MREQ are

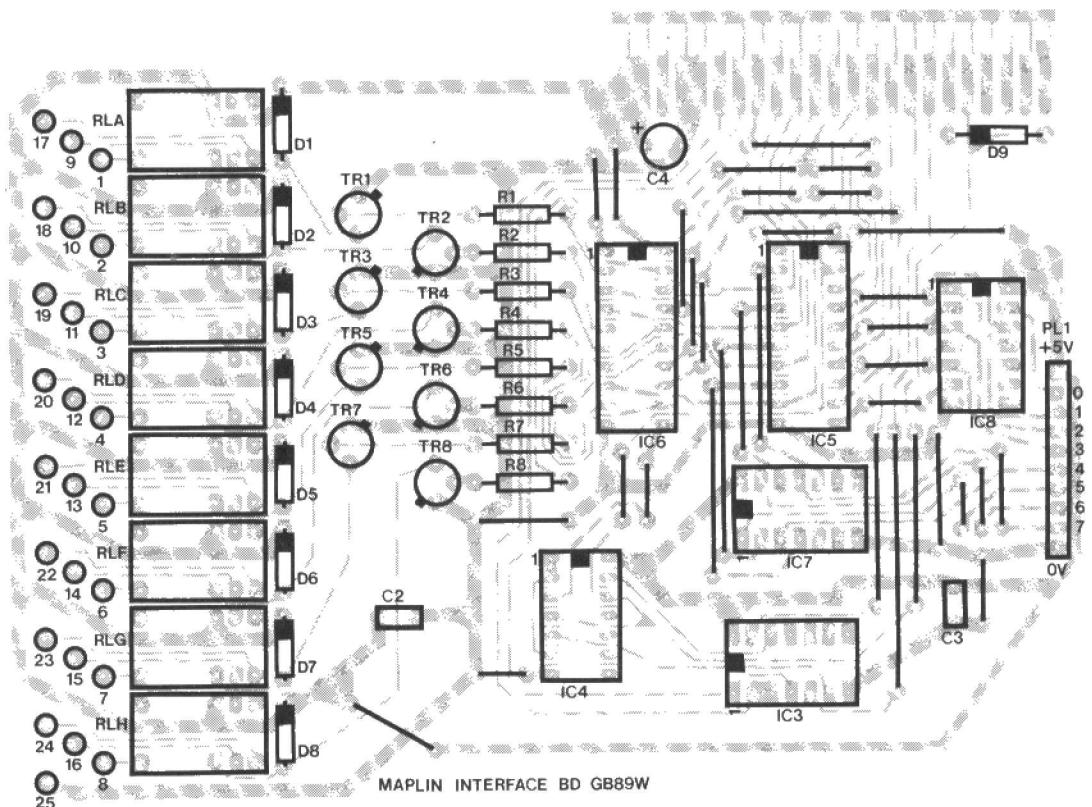
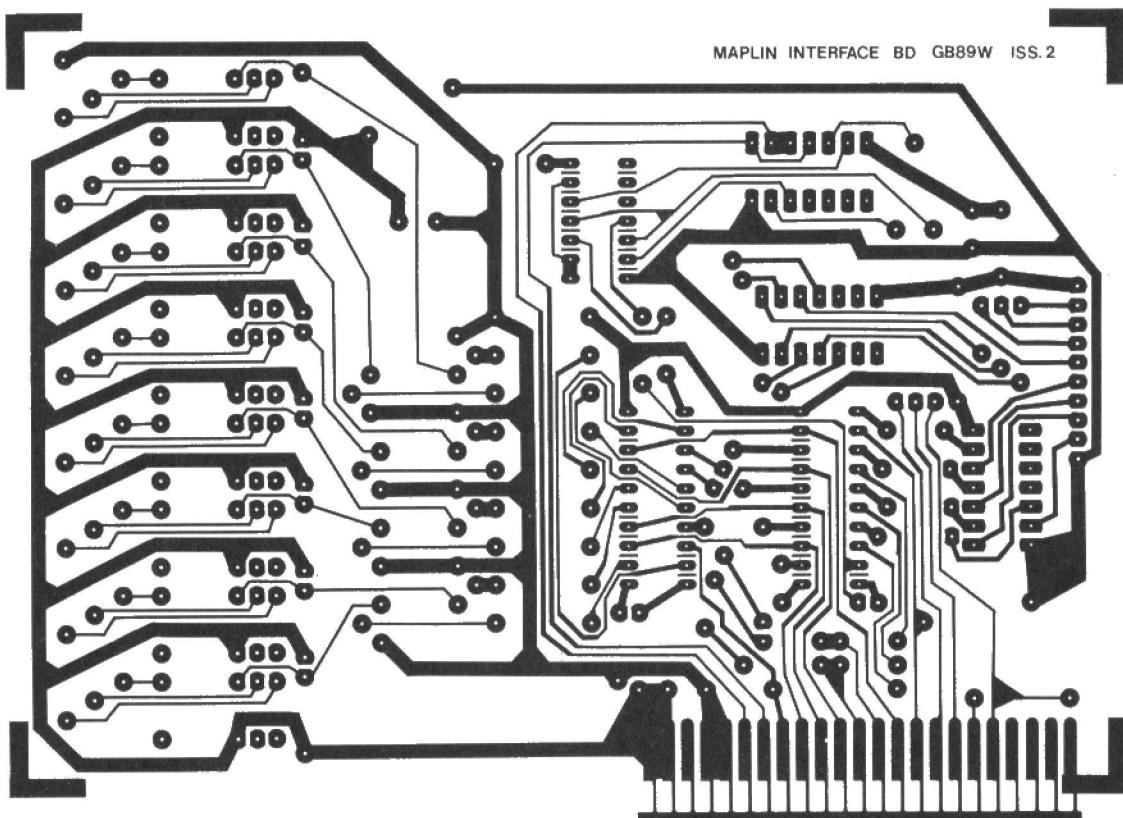


Figure 3. Interface PCB artwork and overlay.

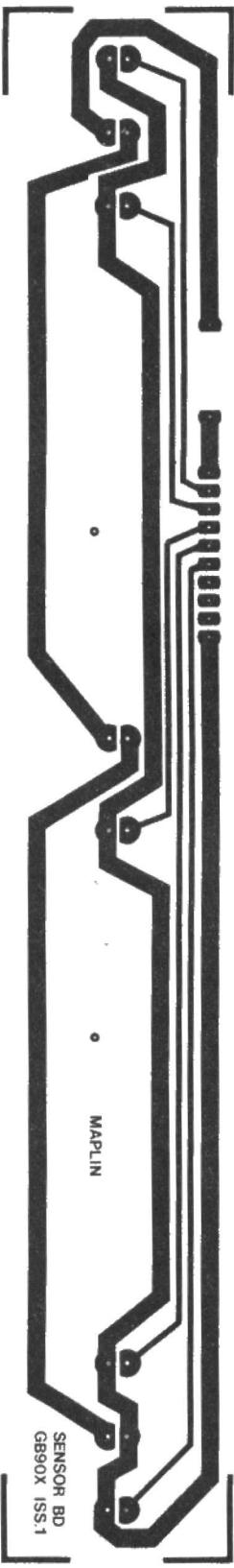
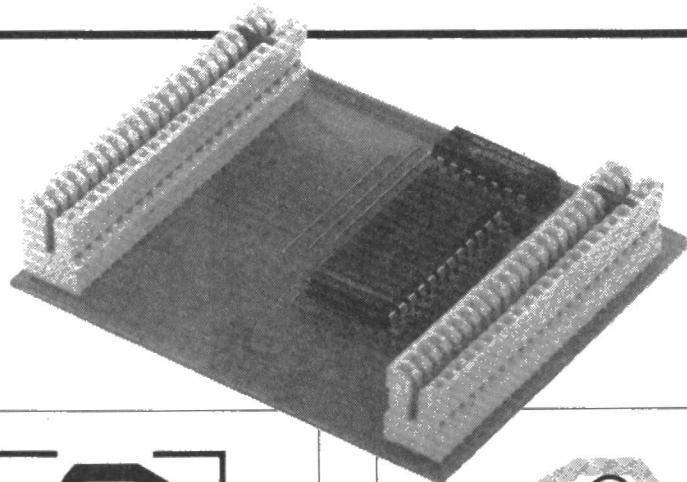


Figure 4. Sensor PCB artwork.

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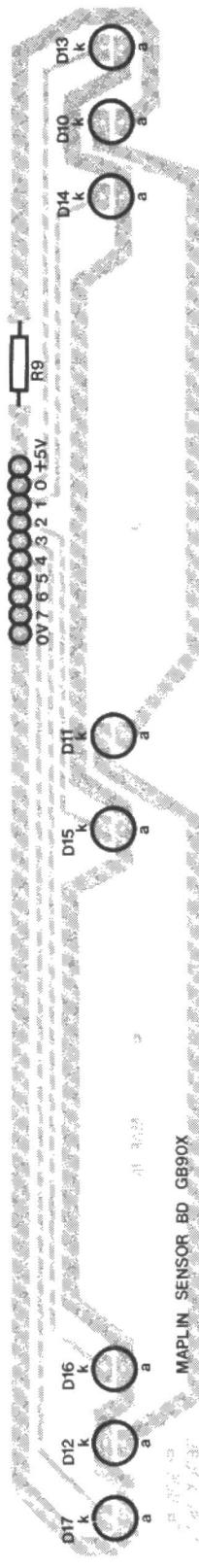


Figure 5. Sensor PCB overlay.

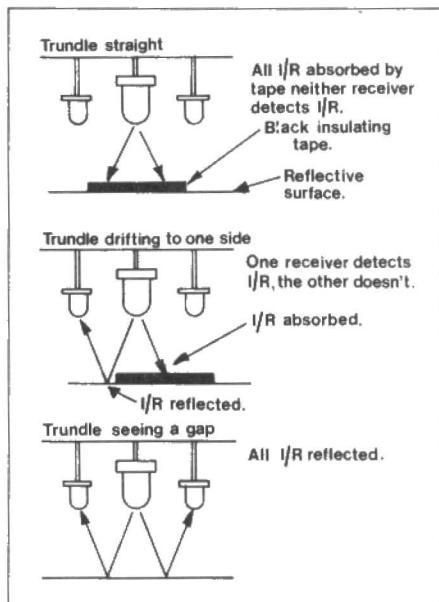


Figure 6. Infra-red detection principle.

low simultaneously. This decoding is essentially the same as that performed in the ZX81's ULA which normally selects the RAM when required. However, the RAMCS line cannot be used as it must be pulled high permanently to disable the internal RAM.

## Trundle Bits

In this category fall all the extra bits necessary to make a ZX81 based 'Trundle' robot which is designed to negotiate a twisting passageway defined by black lines. A sensor board and chassis are supplied in kit form.

The design of the sensor board is simplicity itself. See Figure 4. When Infra-red from one of the TIL38 IR transmitting diodes is reflected into one of the photo-transistors, its collector-emitter resistance falls dramatically, pulling the appropriate input line to 0V. When no IR is detected the resistance of the collector-emitter junction becomes extremely large and the input of the port is effectively left floating high. As the signals are inverted by the Schmitt triggers in the interface, a high will appear on the appropriate data line when IR is detected and a low when none is perceived.

The photo-transistors are arranged so that they may provide an indication of Trundle's orientation in a passageway, where there are walls etc. See Figure 6.

The chassis and motors are also supplied in kit form but the well-documented instructions make assembly an easy task. The motors are switched by the relays in the interface. See Figure 7.

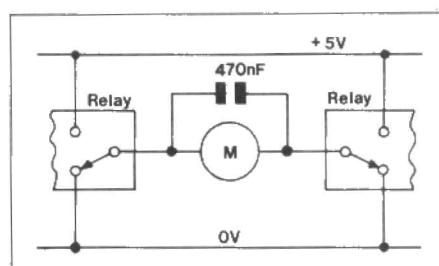


Figure 7. Motor drive.

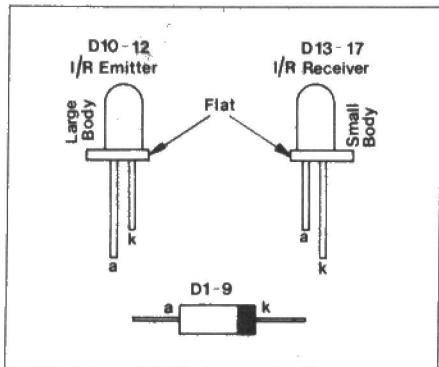


Figure 8. Components pin-outs guide.

## Construction

Provided you take care and obey a few simple rules, your circuits will work first time. Too much haste or carelessness inevitably leads to disappointment.

1. It is critical which way round most components are connected. With semiconductors, if you switch them on connected the wrong way round, you will not get a second chance; they are destroyed in a few millionths of a second. The legend on the printed circuit board will always tell you the way the components should be connected.

The microchips have a 'U' shaped slot in the plastic package. This aligns with the 'V' shaped slot in the socket. The transistors have a tag on the case. The diodes D1 to D4, and D9, have a thick band at one end. The diodes D10 to D12 have the anode lead longer, and D13 to D17 have the anode (collector) lead shorter. See Figure 8. The capacitor has a + sign by one lead.

2. Use a miniature soldering iron. When it has heated up, wipe the hot tip on a piece of wet sponge to clean it. Do this regularly to remove excess solder and flux.

Hold the soldering iron so that it touches both the copper track and the component lead and after a few seconds apply solder to produce a 'volcano' shaped joint as shown in Figure 9.

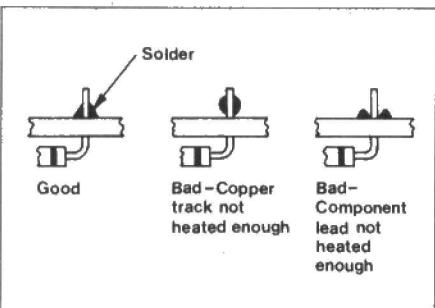


Figure 9. Solder joints.

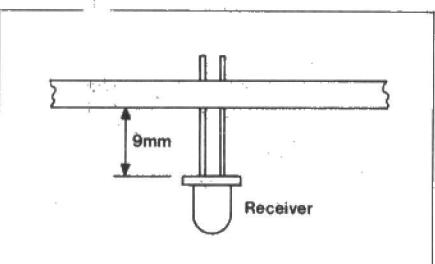


Figure 10. Mounting Infra-red detectors.

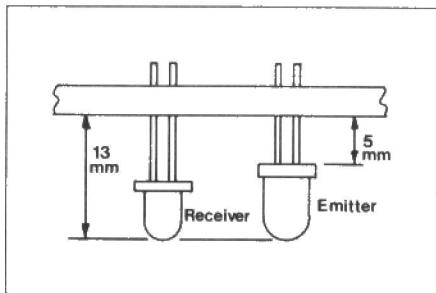
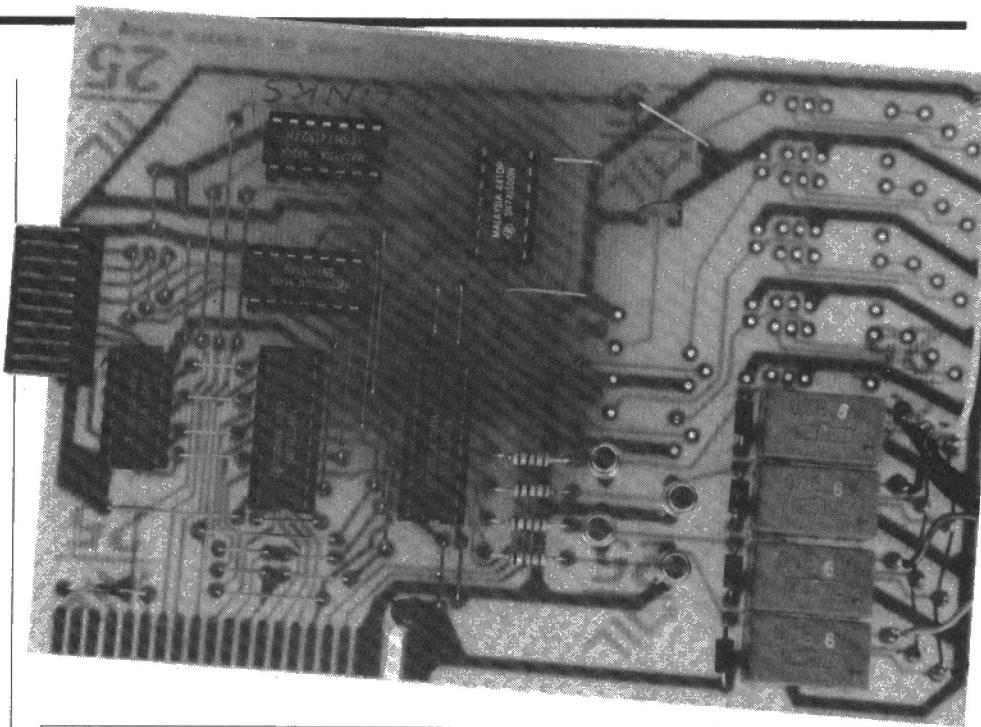


Figure 11. Mounting Infra-red emitters.

## The Sensor Board

With reference to Figure 5, solder the  $10\Omega$  resistor R9 in position. The infra-red detector transistors can be identified by the fact that they are transparent and smaller than the emitters.

Insert the transistor into its holes, making sure the emitter and collector are the right way around. See Figure 8. Hold the transistor so that it stands 9mm proud of the board and solder it in place. See Figure 10. Repeat the process for the other four transistors. *Do not clip off these leads.*

Now solder in the emitter diodes, noting that the longer lead goes to the 'A' sign. Position them so they are level with the transistors; see Figure 11. Again, do not clip off the leads.

Cut a 22cm length of ribbon cable and strip off the white, grey and violet leads, leaving a 7-way cable. With a sharp knife, separate the leads from one another for a length of about 1cm at both ends. Remove the insulation from each wire for a length of about 2mm. Make sure the wire strands are tightly bunched together and solder one end to the 'minicon' terminals. You can then push the terminals into the 10-way housing as shown in Figure 12. Do take great care when doing this work as odd straggling wires will cause shorts.

The board is now finished. Check it carefully for solder joining tracks together. Also check that the components are inserted the right way round. The diodes and transistors have been left with long leads for final adjustments.

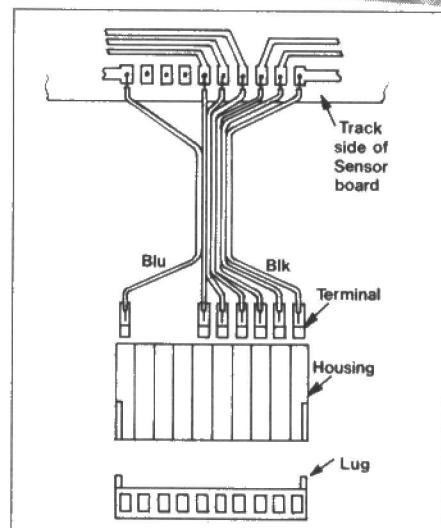


Figure 12. Wiring to Minicon terminal socket.

## The Memory Board

Solder in the six link wires and clip off the surplus leads. Solder in the IC sockets as before, ensuring they are pressed firmly home and the notch faces the same way as on the legend. Solder in the multi-way edge connectors so that the bar on the legend, lines up with the locating peg in the socket. Solder in the

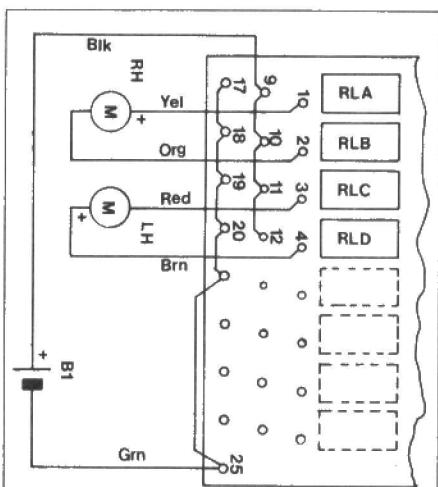


Figure 13. Wiring motor to interface PCB.

$0.1\mu F$  capacitor C1; this may fit in either way around. Clip off the surplus leads.

Push the 74LS00 into its socket. The 6116 memory chip is sensitive to static electricity so precautions should be taken when fitting it. Always leave it in its box until required. Touch an earth if possible; then touching the pins as little as possible, plug the IC into its socket. Cut off all excess leads.

Inspect the copper tracks carefully to make sure you have not joined any tracks together with solder; if you have, remove it with the soldering iron.

You can now test the board. Plug it into the back of the ZX81, pushing it home firmly. Switch the computer on; you should see a 'K' in the bottom left-hand corner of the TV screen. Now type in:

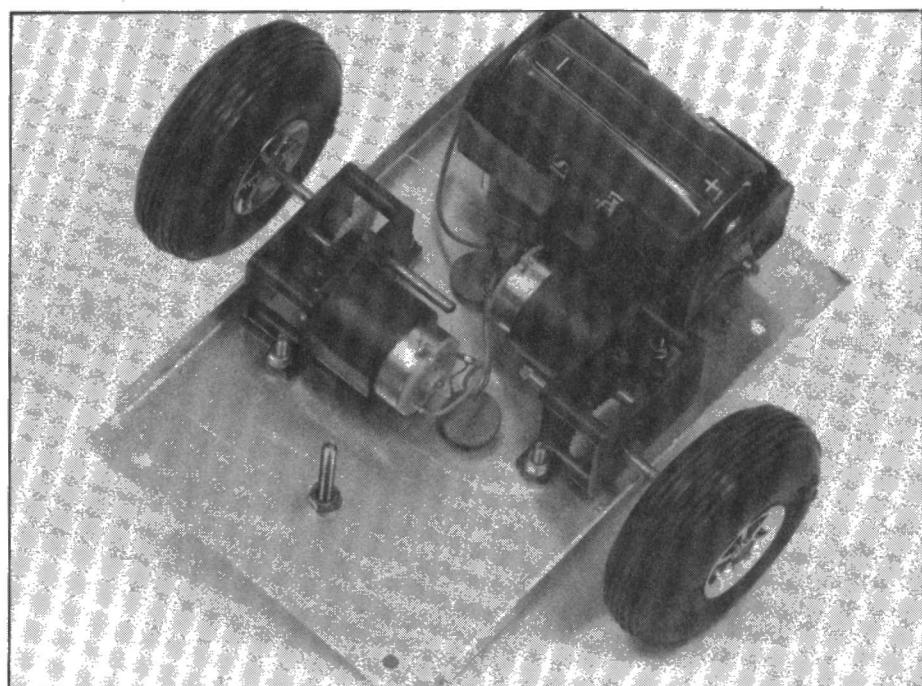
PRINT PEEK 16388 + 256 \* PEEK 16389  
'new line'

You should see the number 18432 in the top left-hand side of the screen.

You can, if you wish, use the ZX81 with this board only plugged in like this, as the available memory is now nearly doubled.

## The Main Interface Board

Note that there are no components for relays RLE to RLH, transistors TR5 to TR8, resistors R5 to R8 or diodes D5 to D8. This is because the interface board has been designed to be able to cope with future developments.



First install the link wires. Cut each wire about 8mm longer than the distance between the holes (marked with a bar on the board). Bend the bare ends at right angles to the length of the wire; offer these ends through the holes and solder into place. Trim off any surplus wire above the solder.

Now solder in the six sockets. Note that they have a 'V' shaped notch at one

end. This is to help orientate the chips the right way around. Solder in the 10-way 'minicon' plug assembly with the long shafts pointing out from the board. Take one of the BC109 transistors and note the tag which identifies the emitter. Push the transistor TR1 into its holes and solder into place. Trim off the surplus leads. Repeat the process for TR2 to TR4.

Take one of the 1N4001 diodes and

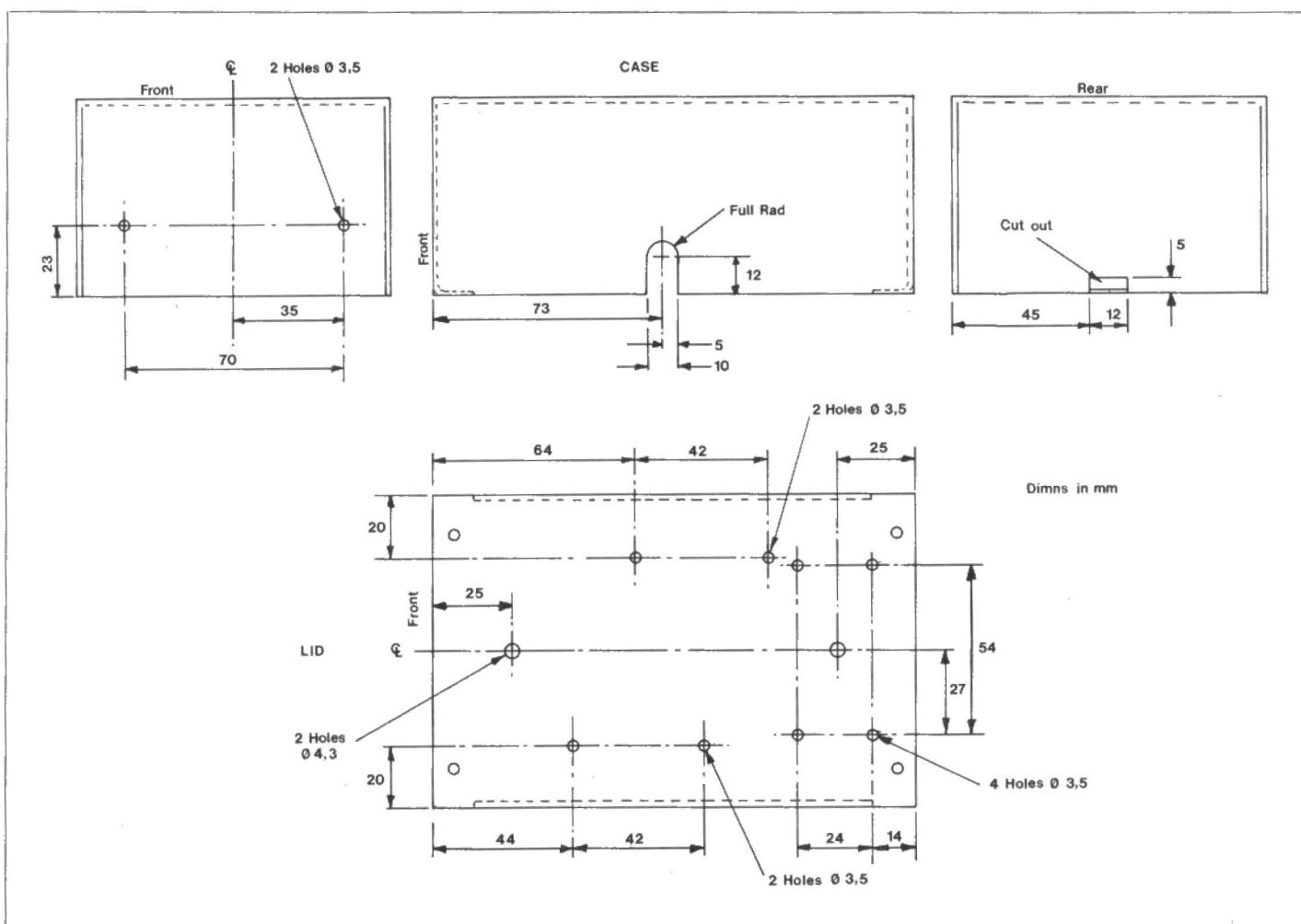


Figure 14. Box drilling details.

note the silver band which identifies the cathode. Repeat the process for the other three 1N4001's. Now fit D9 with the thick band on the diode lining up with the thick band on the legend. Solder in place and trim off the surplus leads.

Solder the resistors into positions R1 to R4, and trim off the surplus leads. These may fit either way round, but it looks neater if they are all the same way.

Carefully offer a relay into position RLA, pushing it firmly home, and solder it into place. Repeat the process for RLB to RLD.

Take the  $10\mu F$  tantalum capacitor and note that the longer lead is marked +. Offer the capacitor into position C4 with the + mark on the capacitor adjacent to the + mark on the board, and solder into place. Trim off surplus leads. The two  $0.1\mu F$  capacitors, C2 and C3, can be put in either way round. Solder into place and trim off the surplus leads.

Take thirteen of the Vero-pins and push them firmly through the holes P1 to P4, P9 to P12, P17 to P20 and P25, from the copper track side of the board until the collar touches the track. Solder them into place.

With the strapping wire, link pins P17 to P20 inclusive, and P25. Separately link pins P9 to P12. Take 30cm of ribbon cable, remove the blue, violet, grey and white wires; strip off 2mm of sleeving from each of the wires and separate them from each other for a distance of 2cm at one end. Attach this end to the board as shown in Figure 13. Carefully press the IC's into their sockets. Check to see the legs all rest in their socket holes and if they do, firmly press the IC home. Now check what you have done. Inspect the copper tracks carefully to make sure you have not joined any tracks with solder. Check again that all the transistors, diodes and IC's are the right way round.

## Chassis and Motors

Drill and cut the two parts of the box which will form the chassis. See Figure 14. You should take particular care when drilling the holes for mounting the motors and sensor board as misalignment here could cause the device to perform poorly.

Assemble the motors and gearboxes as per the instructions enclosed in the motor kit. Use four of the black gears and four spacer washers. You will find the motor will enter its housing more easily if the plastic label is peeled off first. Be careful not to apply excessive pressure when assembling as this may crack the casing. Ensure that the gears all move freely and oil all the moving parts. This will ensure the motors run quietly and will increase their life greatly.

Place the main output shaft of the motor onto a vice or similarly hard object as shown in Figure 15. Place the wheel in position and tap into place with something such as a tack hammer. Do not use excessive force or this may bend the output shaft or break the plastic casing.

Bolt the motors into place with 6BA nuts and bolts, making sure there is a washer on top of the plastic mounting

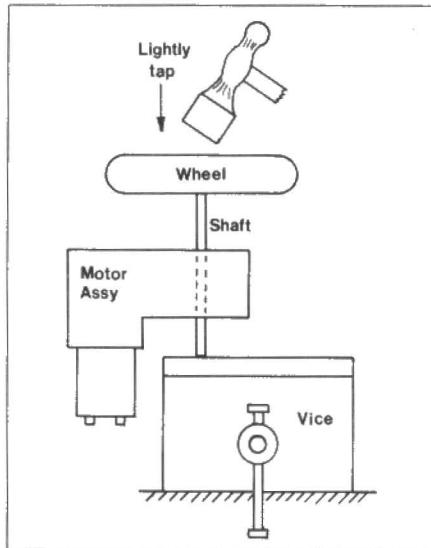
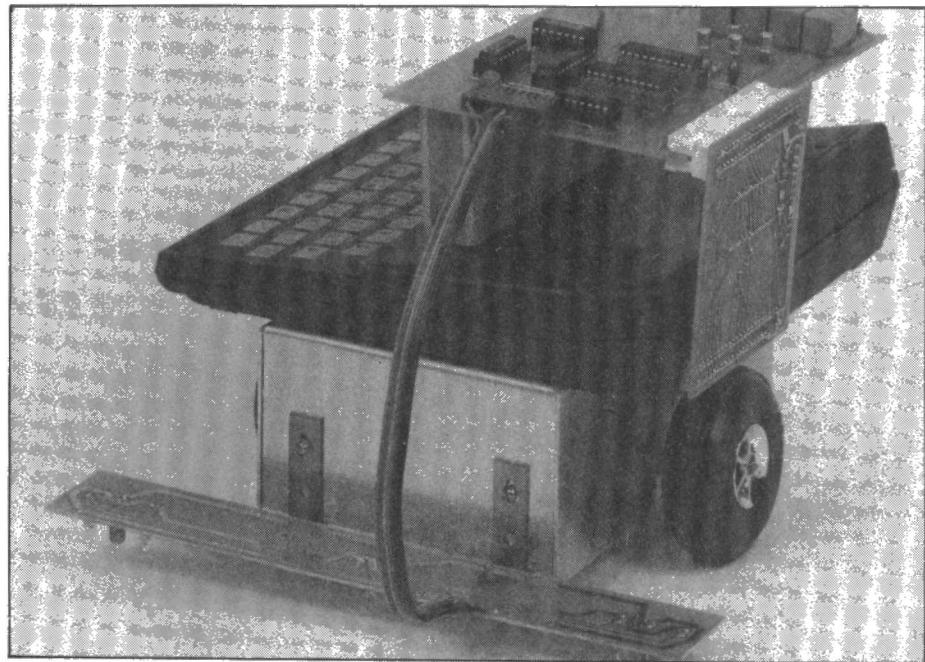


Figure 15. Fitting wheels.

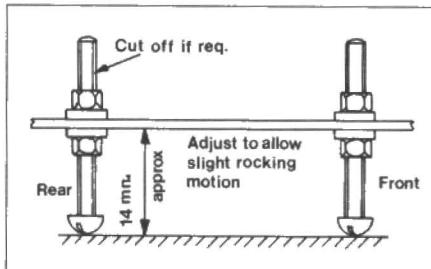


Figure 16. Support bolt skids.

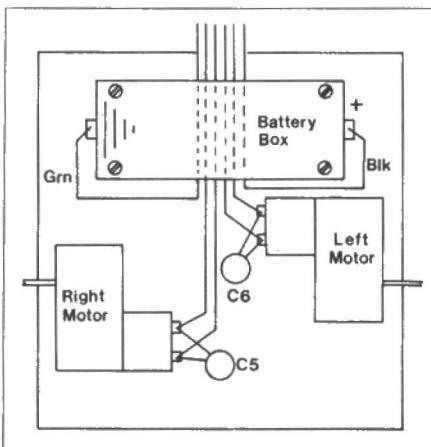


Figure 17. Chassis assembly & wiring.

flange. This will avoid the flange cracking when the bolts are tightened up. Do not use excessive pressure when tightening up as this could break the casing.

Fix the 4BA bolts into place as shown in Figure 16. These act as skids, stopping the chassis rocking backwards and forwards. Bolt the battery box to the chassis using four 6BA nuts, countersunk lin screws, spacers and washers. The spacers fit between the battery box and chassis to allow cable access and room for the skid nut. Take the free end of the cable from the interface board and peel the green and black wires away from the other wires for a distance of 6cm. Peel the red and brown pair from the orange and yellow pair for a distance of 4cm. Separate the yellow from the orange and the red from the brown for a distance of 2cm. Solder the green wire to the negative (spring end) of the battery box and the black wire to the other end (positive). Solder a  $0.47\mu F$  capacitor across the terminals of each motor; it does not matter which way round they are fitted. Solder the yellow wire to the positive of the right hand motor; orange to the motor's negative tag; the brown wire to positive of the left hand motor and the red to the negative tag of same. (The positive is identified by a small + sign cast into the plastic). Mount a U2 or HP2 battery in the battery holder with the positive pointing towards the left motor.

Attach the two brackets to the holes in the front with 6BA nuts and bolts. Bolt the sensor board onto the brackets with the track side up, with the cable leaving from the front of the board, and the bracket underneath the board (i.e. not on the track side). See Figure 18. Make sure the sensor board is level with the base of the box.

With the set of screws provided, screw the box together. The motor-chassis unit is now complete.

Do not try pushing the unit forwards without power running through the motors or you may strip the teeth from the gears in the gearboxes.

## Final Assembly and Testing

Take a piece of wood 10mm thick (approx) by 4cm by 10cm. Push the main interface board into the memory board and the memory board into the back of the computer.

Support the interface board by putting four sticky pads along the long narrow edge of the piece of wood, two on the bottom and two on the top. Place four Quickstick pads onto the top of the aluminium box and stick the computer to the top of the box with the keyboard facing to the right-hand side. To keep the device balanced allow the keyboard to overhang by about 5cm. See Figure 19. Plug in the sensor board connector. The black wire should be nearest the memory board.

## Test Procedure

Support the chassis so both wheels are off the ground. Switch the computer on and type in POKE 9000,10 and press NEW LINE. The two wheels should rotate forwards. Now type in POKE 9000,0 and they will stop. Type in POKE 9000,5 and they will both reverse. Now place the device with the sensor board over a white sheet of paper. Switch the computer on and type in

```
10 PRINT PEEK 9000
20 SCROLL
30 GOTO 10
```

If the sensor board is reading properly, there should be a series of 31's moving up the left-hand side of the screen. If not adjustments will have to be made. Firstly check the transmitter and receivers are between 2 and 3mm above the paper. If they are not, adjust them either by loosening the bolts holding the brackets to the box or if necessary, by melting the soldering joints and moving the components.

If it still does not read 31 on white paper, you can tell which sensors are not receiving as shown in Figure 20. If for example it reads 27, bit 4 needs adjusting. Bend the transistor gently towards the transmitter; this will increase its sensitivity. If it reads 28, both bits 1 and 2 need adjusting, etc. Now check it by putting the sensors over a strip of black PVC tape. It should read zero; if it does not, the sensors are too sensitive. Move the appropriate receiver away from its transmitter a little. Re-check it over white paper again.

To use Trundle, you will need a problem for it to solve. The passage it travels along should be made of black  $\frac{3}{4}$  inch PVC tape on a white surface. We used an 8 x 4ft sheet of melamine covered chip board, but white-coated or painted hardboard would do. If you could find a large sheet of paper, even that will do but make sure it lies dead flat. Mark out your passage carefully in pencil first so the *inside* edges are 16cm apart. When you stick down the tape, don't stretch it or it will creep out of place. You should include left and right turns and dead ends as well as the end

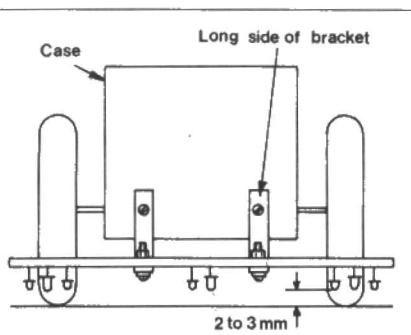
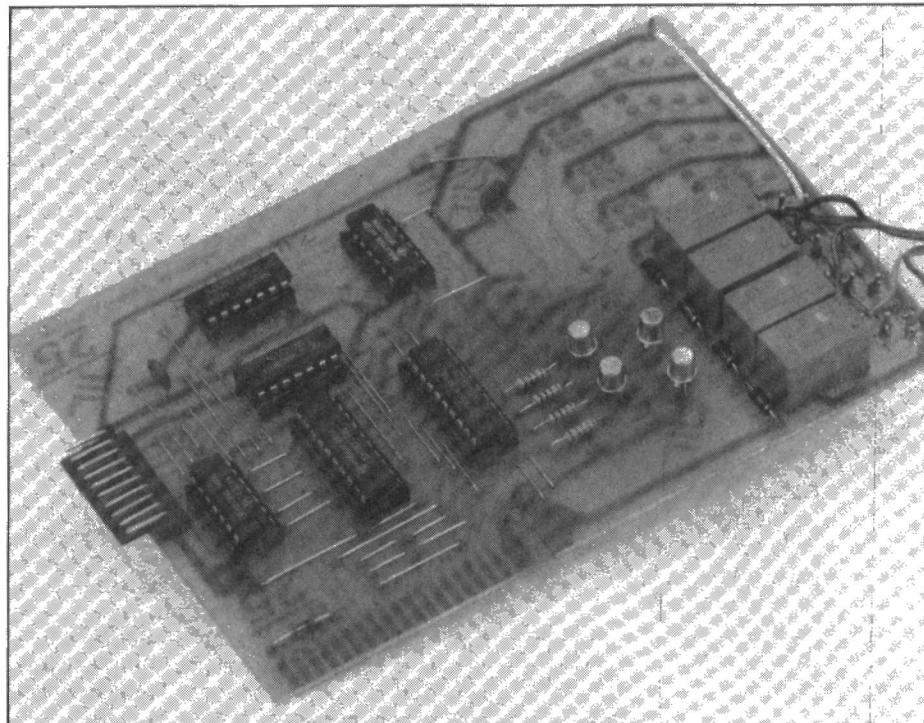


Figure 18. Mounting sensor PCB.

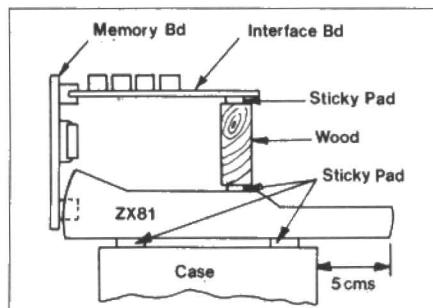


Figure 19. Fixing ZX81 to assembly.

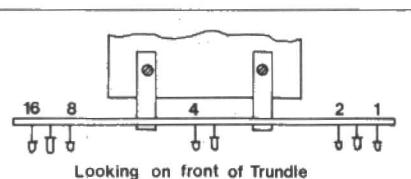


Figure 20. Sensor data bit designation.

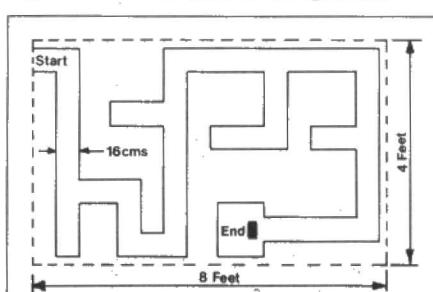


Figure 21. Track layout.

goal. An approximate diagram of our original passage-way is shown in Figure 21.

## Hints on Programming

In the test procedure you saw that 'POKE 9000,10' turned on the motors, both going forwards, and 'POKE 9000,0' turned them both off. The rest of the POKE commands are:

Number Poked to 9000	Result
0	Stop
8	Correct left drift
2	Correct right drift
6	Left turn
9	Right turn
6 & 9 also perform about turns	
10	Forward
5	Reverse

(Any other number poked to 9000 may activate the motors but not necessarily producing a useful movement.)

Place Trundle on a piece of white paper onto which two strips of black PVC tape have been placed 16cm apart. Type in

```
10 PRINT PEEK 9000
20 SCROLL
30 GOTO 10
'NEW LINE'
```

With the outer sensors directly over the black lines, you should see a series of 4's moving up the left-hand side of the screen. If not, move it gently from side to side until you do see 4's. If you cannot achieve a 4, go back to the adjustment section and adjust the diodes for bits 1, 2, 8 and 16. The number 4 appears because only the middle sensor sees white.

If there was only a tape on the right (from Trundle's point of view) Bits 4, 2 and 1 would be activated, so you should read 7. Likewise, if there was only tape on the left, you would read 28 (16 + 8 + 4). Move Trundle about gently and try these.

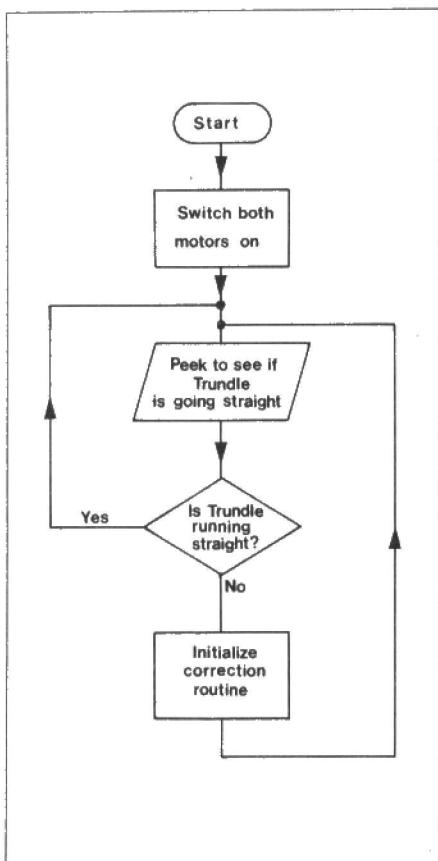
You will need to know what the readings are if it drifts off the straight path. Since these will vary from one Trundle to another, you will have to find these out for yourself. Place Trundle between the two lines so it is reading 4. Now gently push it to the left; the 4 will change (to either 5 or 12). Now push it further, recording all the new numbers until it reaches 31. Repeat the procedure for right drifting and record your results. Make all your readings into a chart, thus:

Reading	Meaning
4	Going straight between two lines
31	No lines (eg. coming out of a "T" junction)
0	Line under all sensors (eg. at the end of a dead end)
7	Only line to the left
6	Line to the left and Trundle drifting to the left
5	Line to the left and Trundle drifting to the right
etc.	etc.

Trundle has achieved its goal if it reads 27, since this is the only time 4 would be de-activated while the others are active.

With lists of all the possible PEEKS and POKEs in front of you, you can now write a program! I would suggest the first thing you do is to write a short routine to make Trundle run along a straight, correcting for drifts. It will appear something like the example Flow Chart shown.

No, I'm not going to write it for you; that's your problem! Now do the same for dealing with bends. It is useful to know here, that as you approach a corner, you can maintain a straight line on one wall.



Flow chart.

Also, if you stop when all the sensors see the black line at the top of a bend, Trundle is exactly in line to turn into the next passage.

Consider all the situations Trundle can get into and write routines for them. One of the most challenging will be to correctly get it out of a dead end. Unless you are careful, you will find that on coming out of the dead end, Trundle will go back to the beginning again. To avoid this, you will have to arrange a 'flag' in the program to indicate that a choice between two possible pathways was made and if you do hit a dead end, you take the alternative pathway on coming out of it.

## Memory Saving

If you can write in machine code, you could probably write a good program in the 500 bytes available in the original ZX81. However, we have assumed you will write in BASIC so we have changed the memory to 2K bytes. This should be adequate provided you are not wasteful. Useful tips are:

1. Keep variable names as short as possible; each character you use costs a byte.

2. Frequently repeated numbers should be replaced with a variable. A good number to substitute with a variable would be the 9000 repeated in the PEEK's and POKE's.

3. Wherever possible, replace 'IF PEEK 9000 = xxx' with LET D = PEEK 9000, so it would now read 'IF D = xxx'. A good place for this type of saving is in your correction routine. Note that this type of saving is not worthwhile in loops where the contents of the input port are being updated continually.

Signs of a nearly full memory are keyboard lock up, i.e. what you type in not appearing on the screen, incomplete screen listings appearing and most annoying of all, a complete crash, signified by the screen going grey. If this happens, you've lost your program - so it is advisable to tape any complicated parts of program you've written as soon as they work. Happy programming!

## Other Uses of Trundle

Firstly note that you can install another four relays if you wish. Space has been left on the board for this. You will of course, also have to put in the extra transistors, diodes and resistors.

The input port will also accept a total of eight lines. The relays can be used to switch any piece of equipment up to a maximum of 24 volts at 1 amp. Note that they are *not* suitable for switching mains electricity. To attempt this would be very dangerous.

The input port will respond to any system that can produce a suitable voltage transition as shown in Figure 22a.

In the dark, this will produce a logical low at the computer. In the light, it will produce a high. Remember there is an inversion through the interface board. In Figure 22b, the preset can be adjusted to trigger a high on the computer port at any derived temperature. In Figure 22c,

when the switch is open, the port will read a high. When closed, it will read a low or if it is more convenient, the circuit can be reversed to give the opposite logic as shown in Figure 22d.

## Specific Ideas: A Burglar Alarm

You could monitor the doors and windows of a house with reed switches held closed with magnets. If somebody enters the house, the computer could be preprogrammed to recognise where the intruder had entered. Then switch on an alarm or tape recorder with a warning message. If you were to set this up permanently, it would be advisable to cut ventilating holes in the ZX81 case and preferably increase the size of the heatsink since the computer does get very hot when it is left on for long periods.

## A Conveyor Belt

Use one of the original Trundle motors to move a conveyor belt made from an old bicycle inner tube. Objects moving along the belt could be monitored by placing light sensitive sensors along the belt. For example, count total

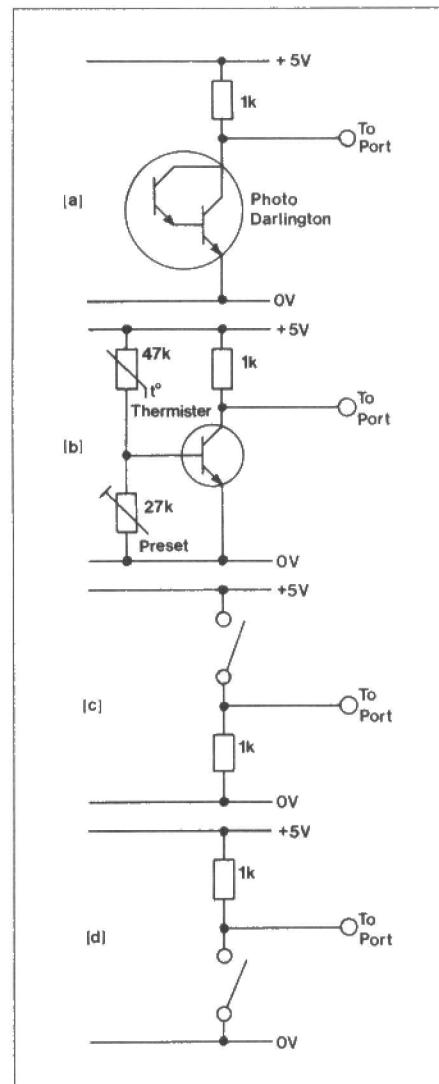


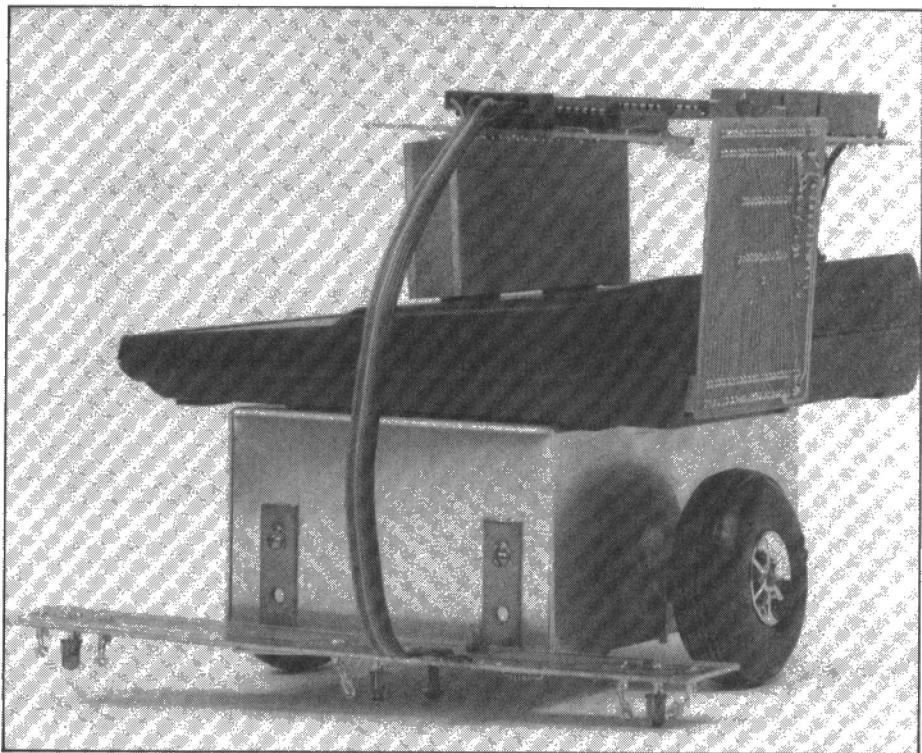
Figure 22. Suggested inputs;  
(a) Light operated,  
(b) Temperature operated,  
(c & d) Switch operated.

bottles passing along the belt with one sensor. Check that each bottle is upright. If one is on its side, stop the belt and use another relay to switch on a relay to push the fallen bottle off the belt.

## Fighting 'Tanks'

The idea is too complex to go into precise details now, however, the general idea is to have two Trundles with sensors to detect visible and infra-red light. Each has a light on top which could be detected by the other Trundle. They can be put into an arena where they would seek each other and fire bursts of infra-red light at one another. They are fitted with a 'soft spot' which, if hit with infra-red, would crash the computer. Obviously if this happened, the 'hit' computer would be 'killed'. No permanent damage would be done - it would simply have to be reprogrammed.

To do this, a fair amount of modification would have to be done and programming such a device would present an amusing challenge. If sufficient interest is shown, details could be published.



## TRUNDLE INTERFACE BOARD PARTS LIST

RESISTORS: All 0.4W 1% Metal Film

R1-4 inc. 4k7

### CAPACITORS

C2,9 100nF Minidisc  
C4 10μF 16V Tantalum

### SEMICONDUCTORS

IC3 74LS27  
IC4 74LS00  
IC5 74LS244  
IC6 74LS373  
IC7,8 74LS14  
D1-4 inc. 1N4001  
D9 1N4148  
TR1-4 inc. BC109C

### MISCELLANEOUS

RLA,B,C,D Ultra-min Relay 6V DPDT  
PL1 RA Latch Minicon Plug 10-way  
14-pin DIL Skt  
20-pin DIL Skt  
Veropin 2145  
Bell Wire Blue  
Trundle Interface PCB

### OPTIONAL

R5-8 inc. 4k7  
D5-8 inc. 1N4001  
TR5-8 inc. BC109C  
RLE,F,G,H Ultra-min Relay 6V DPDT

4 (M4K7)

2 (YR76S)  
1 (WW68Y)

1 (YF18U)

1 (YF00A)

1 (QQ56L)

1 (YH15R)

2 (YF12N)

4 (QL73Q)

1 (QL80B)

4 (QB33L)

4 (BK48C)

1 (RK68Y)

4 (BL18U)

2 (HQ77J)

1 Pkt (FL24B)

1 Mtr (BL86T)

1 (GB89W)

4 (M4K7)

4 (QL73Q)

4 (QB33L)

4 (BK48C)

## MEMORY BOARD PARTS LIST

### CAPACITORS

C1 100nF Minidisc 1 (YR76S)

### SEMICONDUCTORS

IC1 74LS00 1 (YF00A)  
IC2 6116 1 (UF33L)

### MISCELLANEOUS

SK1,2 2x23 Way PC Edgecon 2 (RK36Q)  
24 Pin DIL Skt 1 (BL20W)  
14 Pin DIL Skt 1 (BL18U)  
Trundle Memory PCB 1 (GB88V)

## HARDWARE PARTS LIST

### CAPACITORS

C6,6 470nF Minidisc 2 (YR76H)

### MISCELLANEOUS

Case AC64 1 (XB56L)  
Trundle Motor Assembly 2 (FT41U)  
Trundle Wheel 2 (FT42V)  
Trundle Bracket 2 (FT43W)  
Battery Box HP2 Single 1 (BK46A)  
6BA Bolt x ½in 1 Pkt (BF06G)  
6BA C/S Screws 1in 1 Pkt (BF13P)  
6BA Spacer x ½in 1 Pkt (FW35Q)  
6BA Nut 2 Pkts (BF18U)  
6BA Washer 2 Pkts (BF22Y)  
4BA Bolt x 1in 1 Pkt (BF04E)  
4BA Shakewasher 1 Pkt (BF25C)  
4BA Nut 1 Pkt (BF17T)  
Quickstick Pads 1 (HB22Y)

### OPTIONAL

B1 D Cell Battery 1 (FK57M)

A complete kit of parts, excluding optional items, is available.

**Order As LK62S (Trundle Kit) Price £49.95**

(In addition, a ZX81 computer is required, of course.)

The following are also available separately, but are not included in the 1985 catalogue:

Trundle Interface PCB Order As GB89W Price £4.25

Trundle Sensor PCB Order As GB90X Price £2.45

Trundle Memory PCB Order As GB88V Price £2.45

Trundle Motor Assembly Order As FT41U Price £3.99

Trundle Wheel Order As FT42V Price £1.95

Trundle Bracket Order As FT43W Price 35p

## SENSOR BOARD PARTS LIST

RESISTORS: All 0.4W 1% Metal Film

R9 10Ω

### MISCELLANEOUS

D10,11,12 Infra-red Emitter TIL 38  
D13-17 inc. Infra-red Sensor TIL 78  
10-way Ribbon Cable  
10-way Minicon Housing  
Minicon Terminal  
Trundle Sensor PCB  
Veropin 2145

1 (M10R)

3 (YH70M)

5 (YY56W)

1 Mtr (XR06G)

1 (FY94C)

10 (YW25C)

1 (GB90X)

1 Pkt (FL24B)

# MAKE IT WITH MAPLIN



The title of this article is a catch-phrase which Maplin promoted some 6 years ago. It was one of the entries chosen from hundreds of ideas which were sent in by customers, when a competition was held to find a suitable slogan to adorn Maplin T-shirts. Several years have passed since that competition but the message remains the same and the purpose of this article, which is the first of three, is to provide some 'behind-the-scenes' information and hopefully give a little insight into how Maplin ticks.

Maplin now boasts 12 years of trading from nothing to a massive 30,000 sq.ft warehouse, seen above, building a successful business during a period when many electronic retailers have come and gone. It is rewarding to see how the now famous Maplin Catalogue has become a standard alongside which others are measured. Not many companies are fortunate enough to have success dropped in their laps and Maplin have certainly not had it easy. When the company started, there were critics who suggested that it was not a good time to start a business during a recession, but who could have foreseen how much tougher things would get. The present position this company now enjoys is the result of hard work and a keen sense of judgement, providing the right services and products at the right time.

My story begins in a very average semi-detached house in Rayleigh, Essex, where Doug Simmons and Roger Allen, now the two Maplin Managing Directors, were busy constructing an electronic

## By David Snoad

project. They were hampered yet again, trying to get particular components to complete the project. Locally, it was almost impossible to get all the parts required and when they used postal companies, they could never rely on getting exactly what they wanted and sometimes, weeks would elapse before even a reply was forthcoming. The idea of starting an electronic component mail-order company was born — a company which would provide a fast, reliable service and only supply quality components. From the moment the idea was conceived, socialising went out of the window and there was an immediate halt to the kitchen table amplifier construction; a shame really because the draining board made a great heatsink. The Hi-Fi was sold to help finance the venture and Doug and Roger, along with Roger's wife Sandra, set off on an arduous journey in pursuit of their aim.

The name Maplin was chosen, a name which was linked with the local Maplin Sands and the prospect that the third London Airport may be sighted there, a subject which was very topical at the time. It is amazing that after all these years, successive governments have been unable, to this day, to decide what to do about the airport and we are fortunate that Maplin Electronic Supplies success did not rely on the proposed airport getting off the ground!

The business first operated from a bedroom in Roger and Sandra's Rayleigh home, a room just capable of containing the bare essentials necessary to get this enterprise underway. In those early days, both Roger and Doug worked on the business in their spare time. However, this ended when they realised a twenty-four hour day was just not long enough to go out to work and at the same time, expand a blossoming business concept; a concept which was designed specifically for the electronic hobbyist. It was not many months before the first project designs became available and in fact, we understand that Maplin were one of the first companies in this country to supply circuits which would allow enthusiasts to build an electronic organ at home. Up until this time, most constructors used circuits which were provided in magazines but these were not always as reliable as one would like to have seen.

Maplin produced its first Catalogue, which consisted of 24 pages which listed the range of components stocked, some 1,500 items, a far cry from today's 450 page Catalogue containing approximately 7,000 lines. But they had to start somewhere and I believe that today's Maplin is proof enough that those early customers must have been reasonably happy with the choice of components on offer.

It took precisely 9 months before Maplin outgrew the room which had housed the business during its infancy. A small office was chosen in Westcliff from which the now growing mail-order sales

could be handled. On reflection, we wonder how the new workforce of 7 ever fitted into those first commercial premises but at the time, it was pure luxury after the restrictions of a small bedroom. It was decided to keep the same Rayleigh Post Box 3 address to ensure continuity of trading; that address is of course, the same today. It is a relief the mailing address has remained, since Maplin first started it has been based at five different locations in almost as many years.

Expansion has been closely linked with the growing Catalogue, from those early years up to present day, but another factor responsible for the company's growth was the decision to sell over the counter, i.e. open a shop or rather shops. This decision was taken just before it was necessary to move from the first commercial premises. There had been constant requests from customers to come to the office for advice, or to collect goods, but this was not practical through lack of space. It did not take long to find suitable premises, a shop sited on the London Road in Westcliff-on-Sea and fortunately, with sufficient space upstairs to house the mail-order department. (This first retail outlet can be seen in the photograph).

We will return to the subject of mail-order at a later time. I would now like to concentrate the remainder of this article around the Westcliff shop, providing you with an opportunity to learn a little about the shop, meet the staff and advise you in brief about the local environment. Hopefully, in this way, we can bring you a little closer to the company and the shop team and at the same time, suggest some ideas which you may consider good reason for deciding to visit Southend.

Firstly, I would like to dispel the myth that the mail-order still operates from the Westcliff shop — it doesn't. The office and mail-order department moved on to a warehouse-type facility approximately 8 years ago. Although the mail-order department has since moved again to a larger complex, it is still not practical for customers to visit the Head Office. It is believed that customers receive a better 'over-the-counter' service from staff that understand this side of the business and in any case, if the shop premises had changed location as often as the mail order, there would be a lot of confused



Westcliff's Shop Front Today

hobbyists about.

The Westcliff shop is about 5 miles from the Head Office and is conveniently sited close to the centre of town. Parking is very good, with plenty of on-street parking in both the London Road and surrounding streets. The shop can also be very easily reached by train as it is no more than ten minutes walk from either Westcliff-on-Sea station, which is on the London to Fenchurch Street line, or Southend Victoria station which is on the London to Liverpool Street line.

Once at the shop, you will normally be served by one of four members of staff, who, as in all Maplin shops, try very hard to work as a team rather than separate individuals. This benefits the customer because most of the time, all staff should be able to handle any particular enquiry.

Mr Tony Search is the shop Manager and has been with the company for about 5½ years. Considering that Tony knew very little about electronics when he joined Maplin as a Sales Assistant, he has done well to understand the large range of products he sells and to take on the responsibility of managing the shop. Prior to joining the company, Tony was a professional musician for 15 years. Playing guitar, he toured extensively, playing at clubs and discos all across the UK. Tony also attended many recording sessions, helping to provide vocal backings along with the 4-part harmony group of which he was a member. When the time came to settle down, it was this involvement with music which led Tony to Maplin, because at that time the company were supplying several electronic instrument projects. Before joining



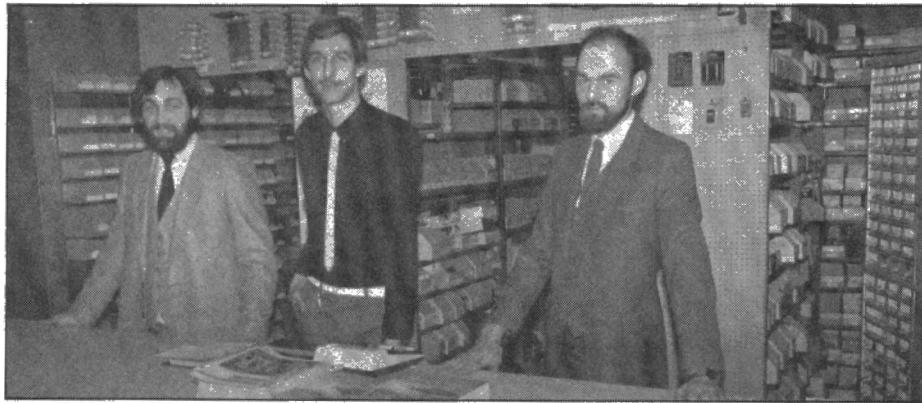
Mr. Tony Search, Shop Manager

Maplin, Tony can remember feeling a little dubious about entering the Westcliff shop as a customer, wondering whether the service was really for electronic engineers and trade customers. He wondered whether he would be self-conscious of his inexperience and whether he could browse around the shop in comfort. He need not have worried; Maplin have always been ready to help the beginner and Tony now, maybe more than most, says "I am always ready to ensure that all my customers get the best service I can provide and people wishing to just browse are always welcome." Tony constantly tries to update his displays to make the shop more interesting and he is proud of the selection of books he has available which is as extensive a range as possible. Tony's hobbies include computer programming, philately and music. He has taught himself the piano and also plays a modern synthesiser which he owns. In addition, he enjoys going roller-skating with two other shop employees.

Patrick Satchell, it seems, is the only member of Westcliff staff who is unlikely to injure himself roller-skating. Patrick is one of the company's longest serving employees having been with Maplin for approximately 8 years. He joined shortly after leaving school and although he started his employment by working in the shop, he spent several years working in the Buying Office, returning to the shop as Assistant Manager when he realised he much preferred meeting the public. Patrick recently got married but he says it shouldn't interfere with his interests which are reading, fishing, listening to



Maplin's First Shop



Westcliff Shop Staff (Left to Right) Patrick, Ricky and Paul

music and electronics, which he has followed since his school days. He also enjoys occasional computing.

Amongst the changes Patrick has seen over the years, none have pleased him more than the introduction of a shop price-list. He points out that this offers a better deal for the customer who travels to the shop to collect goods. It also provides an opportunity for the shops to be more competitive with any local retailers. Since this scheme began, Patrick has been quick to report that sales are steadily improving on the heavier items, and that there has been a marked increase in sales of electrical accessories and cable, where some prices have halved.

Another member of the Westcliff team is Paul Ridler who has been with the company for 2 years. Prior to joining Maplin, he worked for two companies which manufactured and sold model toys and planes. During this period, in his spare time, Paul's experience with models and his knowledge of electronics were put to good use when he became involved with the making of models for film and TV. Links with the arts seem to feature quite strongly in Paul's background; he has helped with lighting and special effects for an amateur theatrical group, volunteered his help at theatres with the setting up of big-name bands such as Pink Floyd and more recently, helped to create a local recording studio. In addition, Paul has a keen interest in the making of video films. He also has a computer but only tends to use it when it can be of assistance with one of his other hobbies. A busy fellow, one wonders how he finds time to go bowling and roller-skating. The latest interest to catch Paul's attention is the subject of robotics. He has recently become involved with the programming of the Heathkit Hero robots which Maplin distribute. This product area is one in which he would like to see Maplin get more involved, especially the domestic robot scene. I am sure he will be pleased when he reads this issue of 'Electronics' and sees the super new robots which will be available from the company.

Last but certainly not least, Ricardo Lorrigan. He has only been with the company 6 months but he has already proved to be an extremely useful member of the team. Although Ricky, as he is usually known, is several years younger than his colleagues, he has,

nevertheless, acquired an excellent knowledge of that all-important subject, electronics. Ricky has been an active electronic hobbyist for many years and has constructed several projects including an Eprom programmer and various computer peripherals. Before joining Maplin, Ricky worked for a well-known electrical retailer for about 2 years. This helped provide the right sort of experience for the job he has now. Amongst Ricky's spare time activities, apart from electronics, he enjoys computer programming. He is also a Radio Amateur which is an asset because various Radio Hams often visit the shop. Ricky likes to keep fit and does so with regular karate training. Another lively pastime that he enjoys is, yes you've guessed it — roller skating!

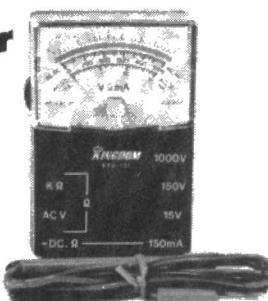
A pleasant group of lads, between them they have a very wide range of knowledge and experience and they would all like the opportunity of serving you to prove that Maplin cares about its customers, whether they are beginners or skilled technicians. The type of customers which currently visit the shop are indeed varied. A large percentage are of course, hobbyists which is most likely due to Southend being a residential town. However, there are several small industrial estates dotted around the town and many of the companies on these sites use the Westcliff shop as an ideal local supplier. Since Maplin introduced educational systems into the product range, the staff have noted increased interest from many schools, colleges and training centres. There are plenty of TV and Radio engineers, also Sound and Lighting engineers from theatres, discos and studios who visit the shop regularly, some seem to think it's their second home. Maplin have, over the past few years, endeavoured to promote trade business; this fact is apparent from the growing number of out-of-town large companies now taking the trouble to collect goods from Westcliff, such as the Ministry of Defence, Marconi, STC, Ford, Ecko Instruments and British Telecom, to name just a few. Companies now appreciate that most of the Maplin range is not only competitively priced when compared with other retail outlets, but competitively priced when compared with other wholesalers. This gradual expansion into trade business has been helped along by the opening of a Trade Sales desk at the warehouse (for

telephone enquiries only) and the introduction of trade quantity price breaks which are shown in the Catalogue. In the near future, this trend will be accelerated when a trade price guide will become available.

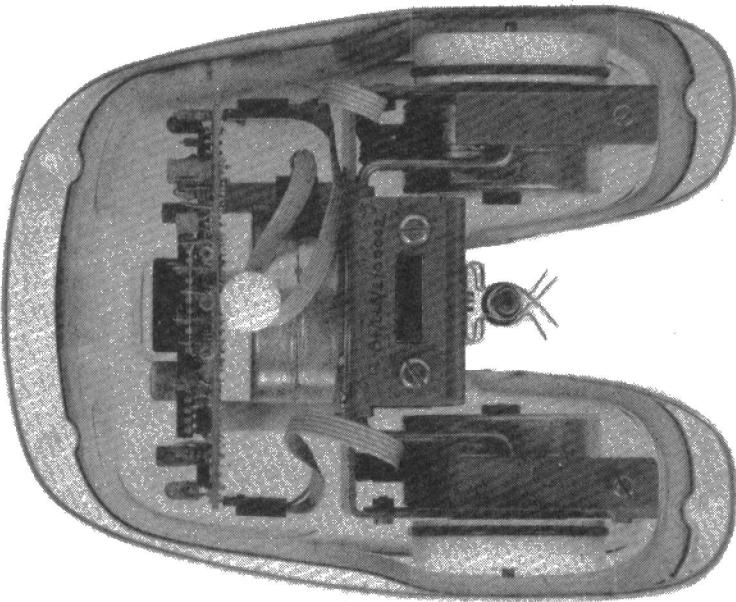
If you are tempted to visit Maplin in Westcliff but need to justify the trip to your partner or family, why not tell them that Southend is a great place to visit. I guess I am biased because I live there but seriously, if you want a day out, there really is quite a lot that you can do or see. Most important for the ladies, an excellent Shopping Centre only half a mile away and for the children, the beach and safe bathing (providing the tide is in). There is sailing and fishing; also, what we believe to be the longest pleasure Pier in the world. The pier head was destroyed in a bad fire a few years ago but it still offers the opportunity for a pleasant stroll. Another part of town where a leisurely walk can be enjoyed is through Old Leigh which offers the character of an old village, fishing boats and the chance to buy some fresh prawns, winkles, shrimps, etc. from the Cockle Sheds. This is where I start getting carried away because I must confess, I have yet to find anything more relaxing than sitting on the sea wall on a sunny day with a plate of cockles and a pint of cool beer! Getting back to town, there is the colourful clifftop gardens and several attractive parks, including Priory Park in which the Old Priory still stands. There is a museum associated with the Priory and another museum in the centre of town in which there is a Planetarium. There are three cinemas, two good theatres and finally, on part of the seafront, there are the amusement arcades, if slot machines turn you on!

The previous paragraph might have been more suited to a tourist information guide, but I have tried to provide not only a look into how Maplin thinks and operates, but a view of how the shop fits into its local environment.

**Free Offer**



In the next magazine, I will provide some background information on two more of the Maplin shops. In the meantime, Maplin is making a special offer to readers of this magazine. If you visit the Westcliff shop before the end of May, take this magazine with you, spend more than £25 and you will receive the Pocket Multimeter illustrated, absolutely free of charge. This offer is only open to customers of the Westcliff shop and is not available by mail-order or at any other shop.



- May be used by any computer with RS232 facility.
- Stepper Motor controlled.
- Designed to draw Logo graphics.
- Half millimetre/half degree resolution.
- Pen Colours easily changed.
- Uses ordinary felt-tipped pens.
- Built-in two-tone horn and LED indicators.
- Built-in line follower.
- Onboard bus connector for easy expansion with plug-in speech board and obstacle detectors etc.

# ZERO 2

## Concept

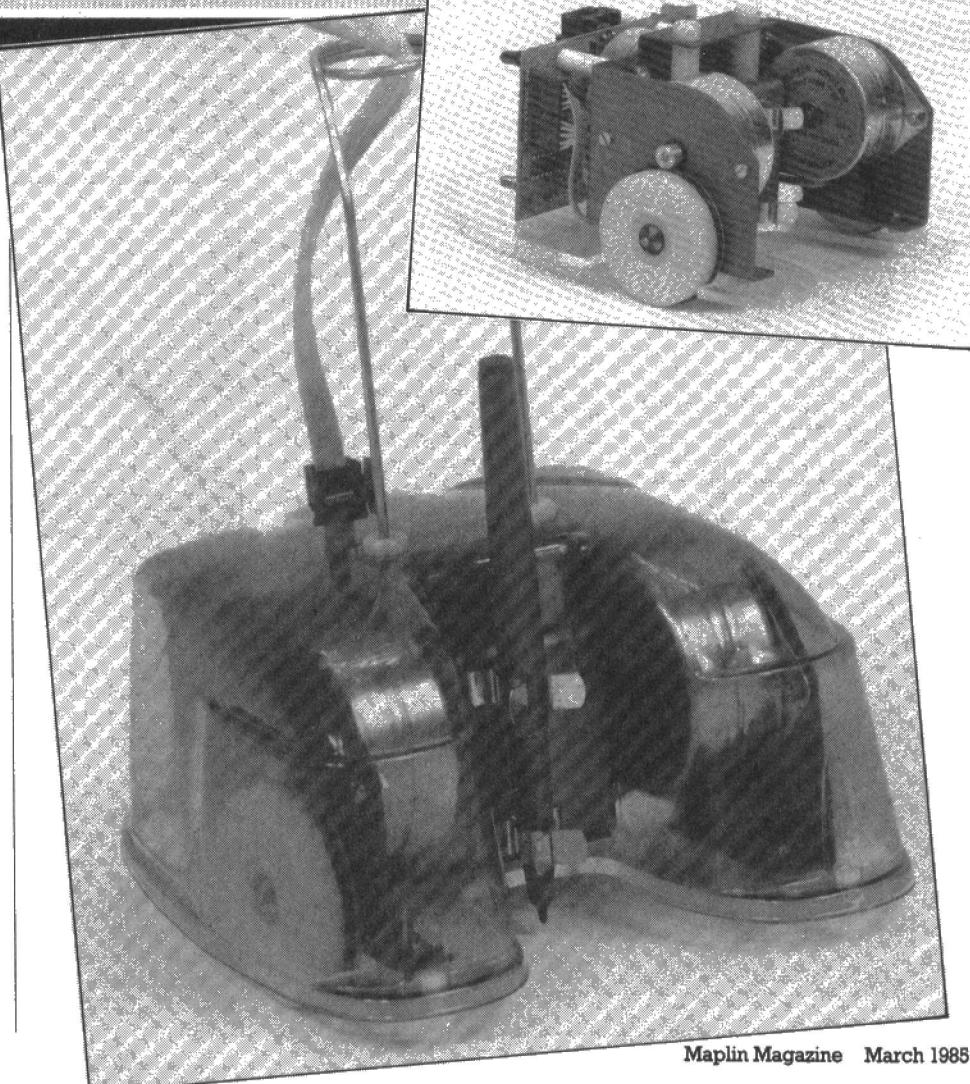
What is ZERO 2? Is it a turtle? - Yes! Is it a robot vehicle? - Yes! Is it even another buggy? - Yes! ZERO 2 is all of these and much more besides; it is whatever you want it to be.

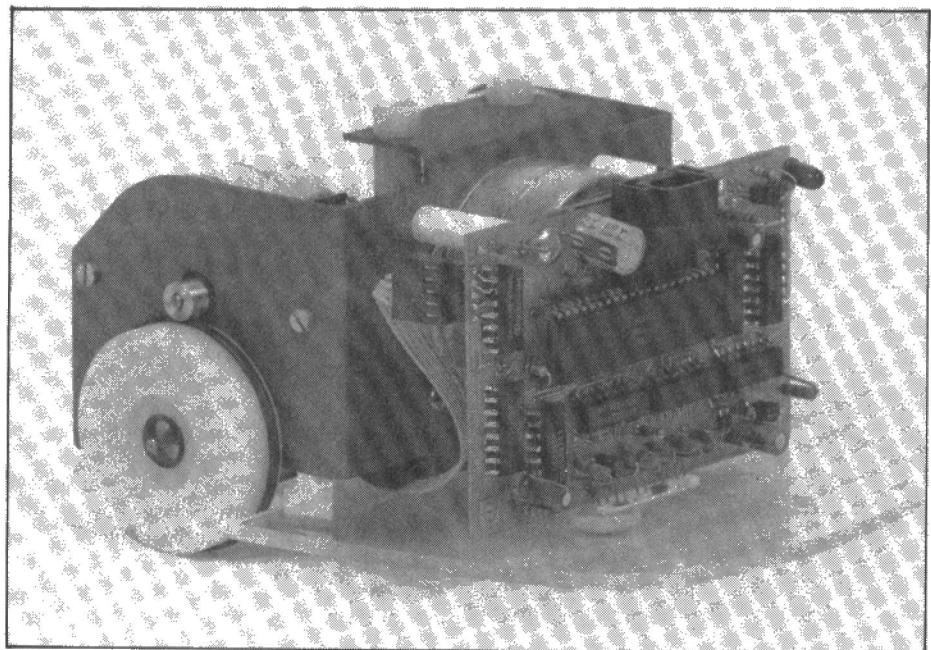
While the idea of electronically controlled robot vehicles is by no means new, it is only in the past few years with the widespread use of microcomputers that it has become a practicality. One of the most frequent questions asked about computer controlled robot vehicles is: "What can you do with it?" However, no one asks the same about a ball - they have been around for such a long time that everyone knows.

ZERO 2 in its primary mode has a built-in function; that of drawing Logo graphics but it is also equipped with LED's to be turned on and off, a two-tone horn that can be sounded and a line-follower. Add-on boards provide speech, obstacle detection and hole sensing so that it doesn't fall off the edge of the table. Like a ball, what you actually do with ZERO 2 is up to you.

## General Description

ZERO 2 is 180mm long, 150mm wide and 90mm high with a transparent shell and baseplate. This is a feature essential to Turtle Microrobots used in Logo programming where viewing of partly completed patterns is desirable.





The machine is driven by two stepper motors, each controlling a wheel in half millimetre steps. The pen is raised or lowered by a third stepper motor. These three motors and the pen lift mechanism are mounted on a rigid aluminium framework, a 'pelvis', which in turn, is mounted on the transparent baseplate. Towards the front of the baseplate, there is a nylon glider, or toe, to prevent ZERO 2 falling over. All the electronics are mounted on a 4in by 2½in PCB which in turn is fastened to the pelvis. At the top of the PCB is a socket, similar to a telephone connector socket but with a different polarisation, to take the power and control umbilical. All the works are protected by the easily removable cover; in buggy mode, leave it off. The umbilical is held clear of the pen by the wire loop halo which plugs in the top of the body.

To allow ZERO 2 to be independent of the make of computer used to control it, the computer end of the umbilical

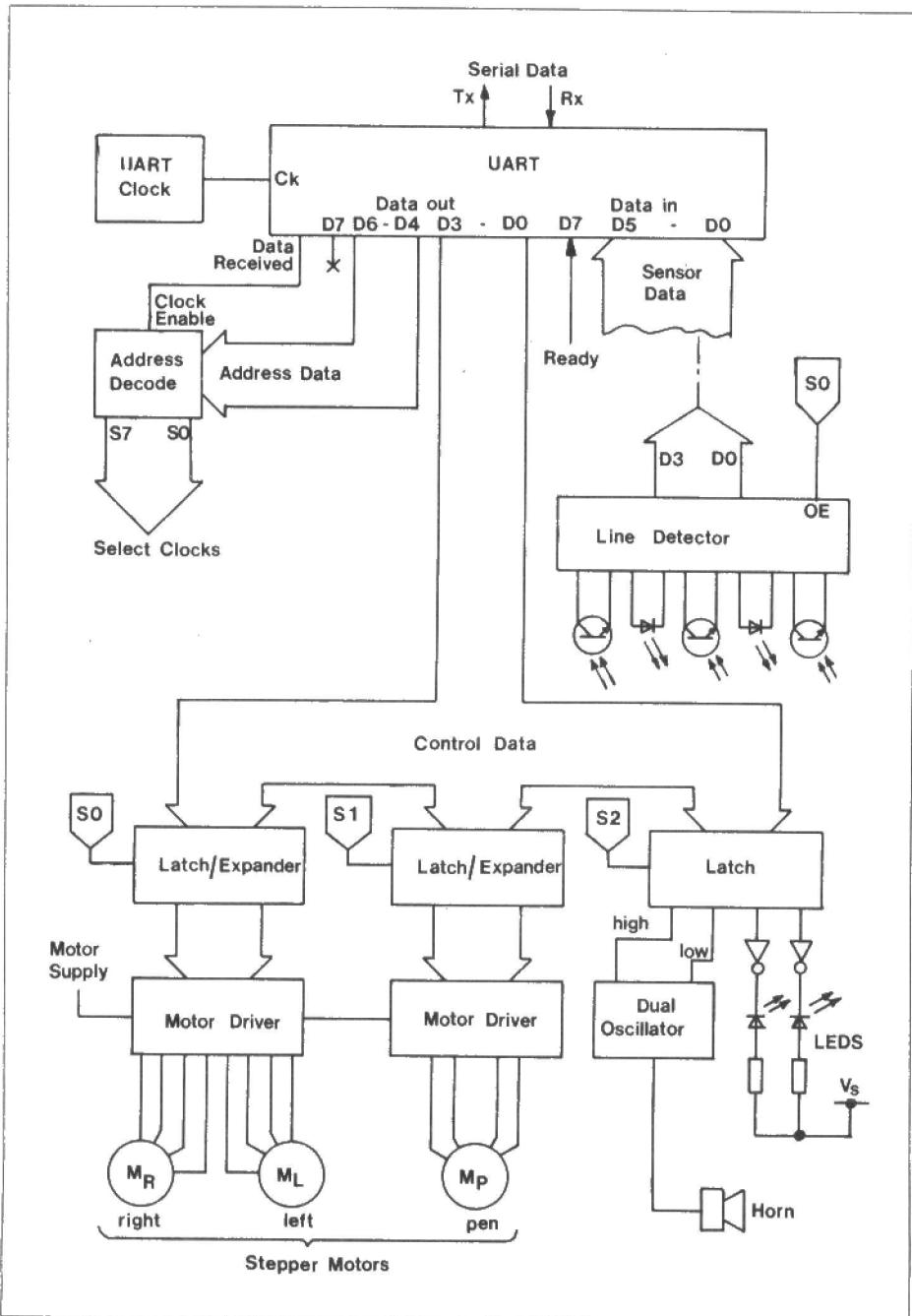


Figure 1. ZERO 2 Control Circuit Schematic

March 1985 Maplin Magazine

1.	Motor Supply	+ve
2.	Motor Supply	0V
3.	Logic Supply	5V
4.	Logic Supply	0V
5.	Serial Data	Out
6.	Serial Data	In

Figure 2. ZERO 2 Umbilical Signals

plugs into a special box which includes connectors for the serial ports of the Commodore 64, BBC B, Spectrum and a 25-way industry standard RS232 D-type connector for all other computers including Amstrad, MSX machines and the QL.

## Mechanical Construction

Some of the parts such as motor drive bosses and rubber axle supports are bonded together with adhesive and this is done in the factory so that only a screwdriver is necessary to complete the assembly, instructions for which are included with the kit.

## Electronic Construction

The PCB is very densely populated with components and consequently has to be double-sided with fine tracks and many plated-through holes; because of this, it is supplied as a ready-assembled and tested item onto which plug the leads to the three motors and the speaker. Having the circuitry ready-built in this way should be seen as similar to buying an integrated circuit as opposed to trying to make an equivalent circuit from discrete components.

S <sub>D3</sub> - S <sub>D0</sub>	Sensor Data Ready
S <sub>D7</sub>	
E <sub>D6</sub> - E <sub>D4</sub>	Address Data
E <sub>D3</sub> - E <sub>D0</sub>	Control Data
DR	Data Received
Spkr	Speaker
5V	
0V	Power }

Figure 3. ZERO 2 Expansion Bus Signals

## Circuit Description

A 6402 UART is wired to accept and send serial data, 8-bits, parity disabled, 2 stop bits at 4800 baud.

The received data is split into high and low nibbles as in Figure 4. D7 is discarded and D4, D5, D6 are used to address a 3 to 8 line analogue decoder. The UART's Data Received output, which goes high when a received byte has been transferred to the output buffer and is stable, is routed through the decoder to form the select clocks S0 to S7. Only S0 to S2 are actually used and these enable the Drive Motor latch, the Pen Motor latch and the Indicators latch as appropriate. S0 is also used to route the line follower output to the UART for transmission back to the computer. The latches used have Q and  $\bar{Q}$  outputs and these are routed from the latches at address 0 and 1 through Darlington drivers to control the stepper motors. Two more Darlington drivers are used to switch the LED's at address 2. The other two data bits at address 2 are used to gate two oscillators, the outputs of each being routed to the speaker.

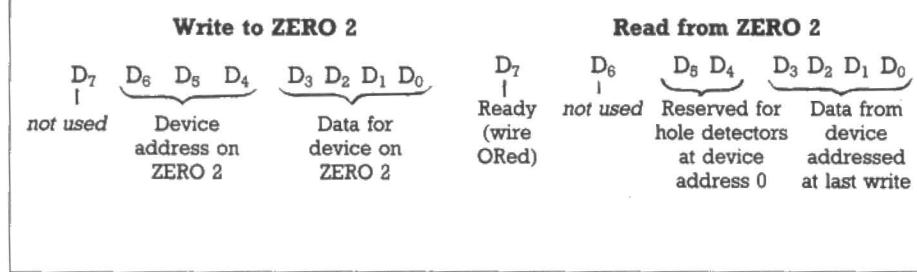
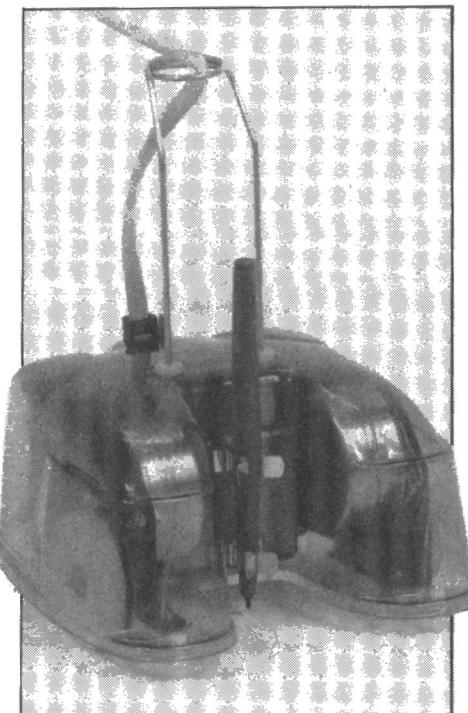


Figure 4. ZERO 2 Programming Model

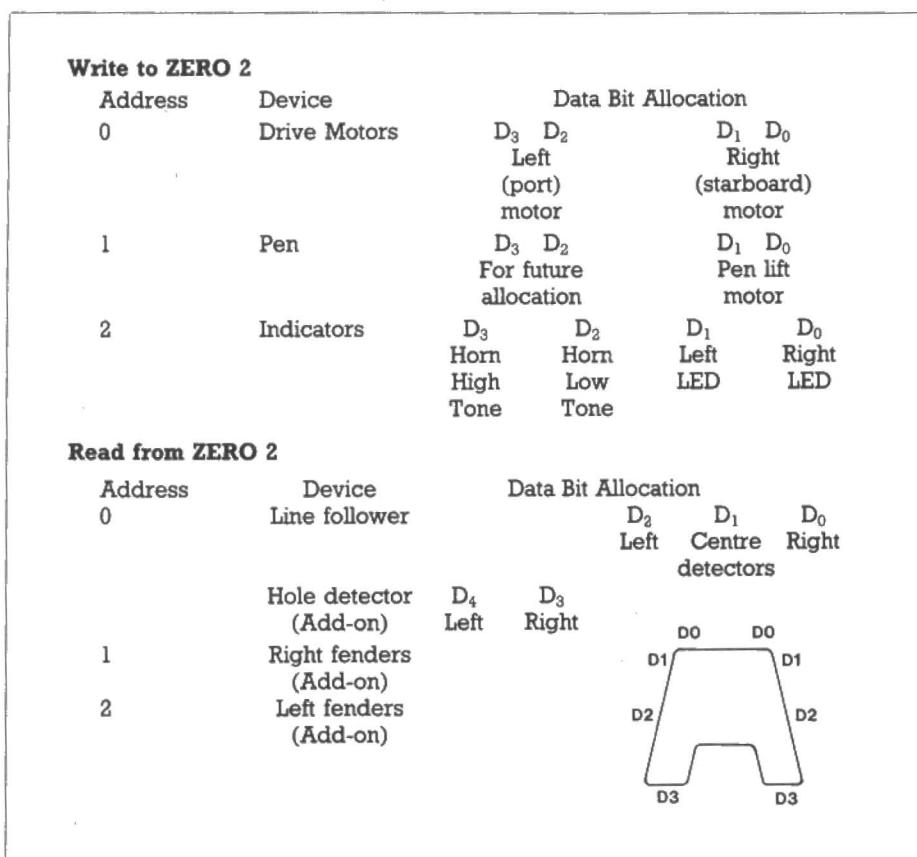


Figure 5. ZERO 2 Device Allocation

## Circuit Expansion

All the necessary signals and power are routed to a 16-pin socket in the centre of the PCB to enable expansion boards to be simply plugged on the front. For those boards which need a Ready line, such as speech boards, D7 of the parallel data accepted by the UART is available; it is intended that this line be wired so that any peripheral board can pull it low.

### Add-Ons

One of the problems with umbilical controlled vehicles is the umbilical itself and one add-on that will shortly be available is an infra-red communications link. For the vehicle end, there will be a backpack containing a rechargeable battery and an infra-red receiver/transmitter unit with a complementary infra-red unit at the computer end.

Most animals have learned the value of audible communication and while R2D2 may get away with squeaks, where humans are concerned speech is much more understandable, hence another

Bit pattern	Decimal	Direction
1 1	3	
0 1	1	Vehicle moves
0 0	0	
1 0	2	forwards
1 1	3	

Figure 6. ZERO 2 Motor Control Codes

add-on board will be a programmable speech system which will plug onto the Expansion Bus connector.

Two other add-on boards that will plug onto the main board will be one for detecting obstacles in ZERO 2's path and another for detecting holes or edges of tables or simply a coloured border round ZERO 2's territory to prevent it straying.

## Programming ZERO 2

Figures 4, 5 and 6 give complete details for controlling ZERO 2 in its basic form. This is easy to do even from BASIC, but to follow a line or detect obstacles bitwise comparison is needed and some versions of BASIC do not support this. In these cases, it is necessary to write a routine in machine code. Such sets of routines are available for the Commodore, BBC and Spectrum either to interface to Logo or to be called from BASIC.

## Conclusion

Robots are going to play an increasing role in all our lives in one way or another and they are not going to get any simpler. In a few years' time, it should be no surprise to see robots controlled by multiprocessor systems with a couple of megabytes of RAM and gigabytes of storage on laser disc. So now is the time to get into Robotics while robots are relatively easy to understand and ZERO 2 is an excellent and affordable way to learn.

Zero 2 is available in kit form exclusively from Maplin.

**Order As LK66W (Zero 2 Robot Kit)**

**Price £79.95**

# FIRST BASE



by Mike Wharton

## A Beginner's Guide To Logic Design.

## Part Eight

### Crystals

In the last article in this series, mention was made of a method for improving the accuracy of an oscillator to be used for timing purposes. The most common method of regulating the frequency of an oscillator is to make it crystal controlled, as many of you will be aware. The material generally used for this purpose is quartz, a naturally occurring mineral which exhibits the piezo-electric effect. This means that if a voltage is applied to the prepared faces of a crystal of quartz then it changes its shape very slightly. Conversely, if a crystal is distorted slightly by the application of pressure, then a voltage is generated across the same faces. By carefully cutting the crystal of quartz to an accurate size and shape it is possible to ensure that it resonates at a particular frequency, rather like a tiny bell. If such a device is placed in the feed-back path of an oscillator circuit, then the maximum feed-back will occur at the resonant frequency of the crystal and the vibration of the crystal, and hence the oscillation of the circuit, will be maintained. Quartz is chosen since it is cheap, exhibits a fairly marked piezo-electric effect and can be made to have a very low dependence on temperature. For highly critical applications the crystal may be contained in an oven, where the temperature is thermostatically controlled. For most everyday applications this is not necessary, and the accuracy of the modern digital watch is as much a tribute to the crystallographer's art as it is to the silicon sculptors.

Reference to Figure 1 will give some idea of what the crystal looks like when fitted with its hermetically sealed tin can overcoat, and the latest Maplin Catalogue will give some more information about commonly available types. One point that is perhaps worth mentioning here is that of the 3rd and 5th overtone types. Like a violin string a crystal will vibrate at its lowest or fundamental frequency, as

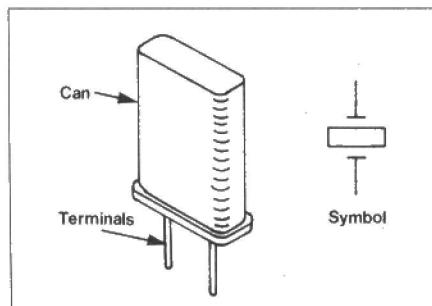


Figure 1. Quartz crystal

shown in Figure 2a. However, both string and crystal can be made to vibrate at higher frequencies, and the third harmonic mode is illustrated in Figure 2b. A 3rd overtone crystal has been specially cut so that it will vibrate in this manner, at a frequency three times higher than its fundamental. It is a matter of physics that

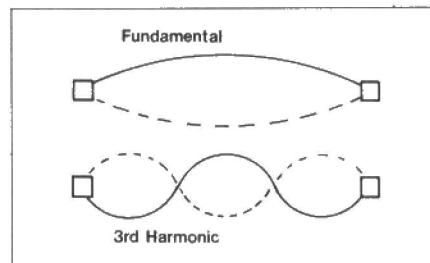


Figure 2a & b. Fundamental and 3rd harmonic types

the size of the crystal must reduce for an increase in resonant frequency, and to obtain the higher frequencies with the fundamental mode would mean trying to cut impossibly small crystals. A circuit for using overtone crystals will therefore contain inductive elements in order to operate at a nominal high frequency, and the presence of the crystal will ensure this is accurately maintained.

### Crystal Clock

Figure 3 shows a typical arrangement for using a quartz crystal with logic

gates to produce a clock oscillator. Of course, discrete transistors could well be used in any manner of oscillator circuit, but it is often more convenient to use available gates in existing devices within a design. Here the logic devices are being used in a so-called 'linear' mode, that is as amplifying elements, with the crystal fixing the frequency of oscillation. In this application the frequency will be the fundamental of whatever crystal is used, be it an overtone type or not. This

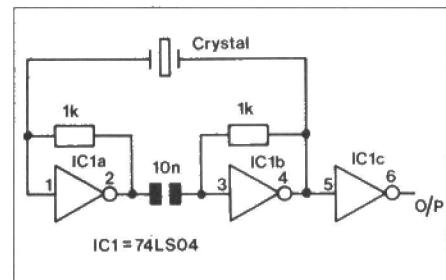


Figure 3. Crystal oscillator using logic gates kind of circuit will be found in many designs where an accurate clock is required, from expensive microcomputer controlled machines to our humble hi-tech egg-timer!

Whilst for many applications the use of a crystal provides an accurate time-base, it may also replace one problem with another. For instance, if we desire to count seconds in a simple timer it is impossible to provide a crystal controlled clock oscillator with a frequency of one hertz. Usually the basic frequency will be at least some tens of kilo-hertz and this will need to be divided down to give the desired clock rate. In a digital watch a small crystal is used which has a fundamental frequency of 32.768kHz, and this is passed through a sequence of 16 dividers to produce a 1 hertz clock. For some mains powered equipment a 50Hz back-up clock needs to be provided in order to keep some vital processes going until the power is restored. In this case a 3.2768MHz crystal would be used instead.

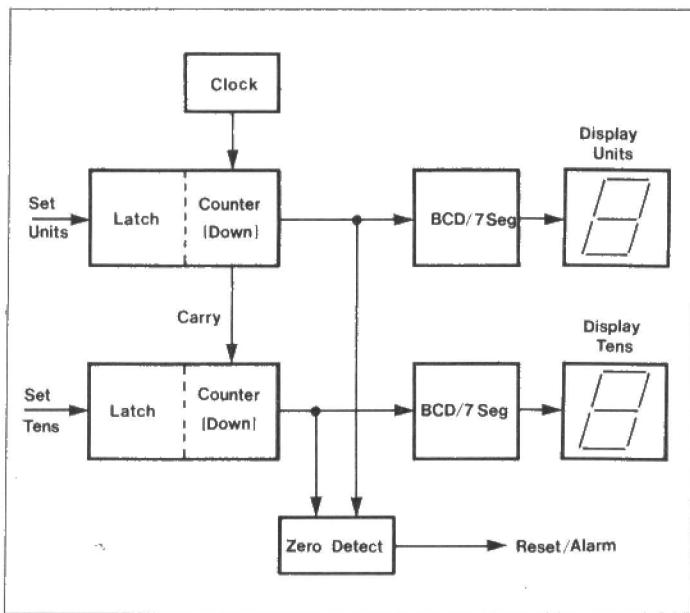


Figure 5a. Down counter

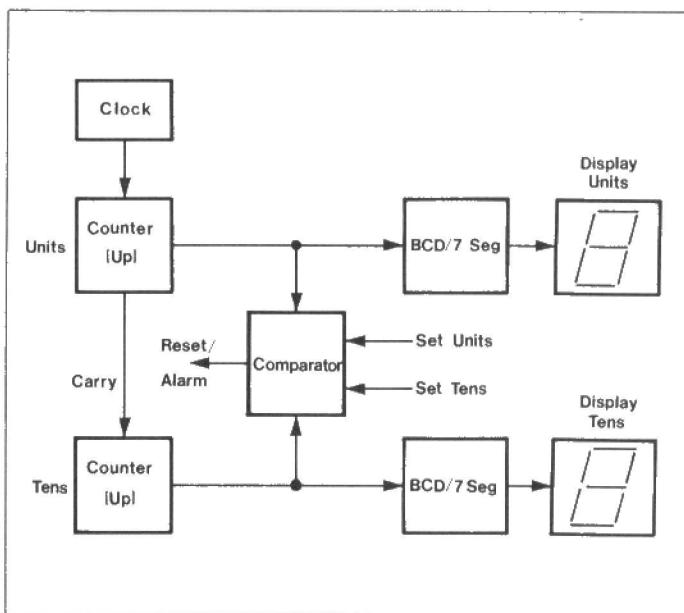


Figure 5b. Up counter

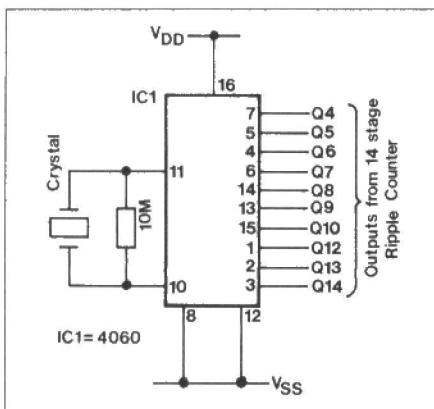


Figure 4. CMOS 4060 clock

To produce a clock by using discrete logic elements for the oscillator followed by up to 22 division stages would require a lot of unnecessarily expensive chips. The whole operation can be achieved by the use of special chips, which contain an oscillator and many dividers in one package. One example of such a device in CMOS logic is the 4060, and Figure 4 shows how this may be used by the addition of a suitable crystal and the various frequencies tapped off from the outputs from the divider chain. Such a clock could be used to replace the simple 555 timer circuit used previously for a 1Hz clock timer. This probably represents an over-kill for this application, but if a crystal is available it is instructive to set up the circuit on a bread-board, especially if an oscilloscope is available to examine the outputs from the dividers.

## Egg Timer

At the end of the last article it was suggested that you think about how the simple timer unit given could be improved to make it more versatile. There are almost limitless ways in which this could be achieved, and rather than giving a single complete method we shall continue by examining various options in outline. Hopefully this will give sufficient insight into the techniques to allow you to devise your own digital egg-timer.

One fairly important requirement for a timer is that it should be possible to set it to indicate a certain lapsed time. For practical reasons we shall limit ourselves to periods of less than 10 minutes, but the techniques can be taken as far as you wish. The solution adopted may be to set the desired time and then count down until zero is reached, or to start from zero and count up until the lapsed time is detected. In each case some form of 'memory' will be required. This may hold the initial value of time, which is then decremented, or to hold a time value with which each incremented value is compared until a match is found. This 'memory' could be a semiconductor type or switches set to the desired time value. Besides this a clock will be needed and possibly a display to indicate how far timing has progressed.

Let us now examine how each of these solutions may be put into effect. Figures 5a and 5b are block diagrams of

each one. In the first example most of the requirements have been dealt with in previous issues, but one which has not is the method of setting the time value in some sort of memory. This could be done with some RAM and associated circuitry, but is more economically achieved by using Presettable Up/Down Counters. These are a special type which can be set to hold some desired value before being clocked down to zero; the arrival at zero may then be used to initiate a reset or alarm. Figure 6 gives a design using two 74LS192 presettable BCD up/down counters. This has one set of inputs, D0 to D3 and one set of outputs Q0 to Q3. When pin 11, PL (Parallel Load), is pulsed low the value present on the inputs D0 to D3 is latched into the internal dividers, and then appears at the outputs Q0 to Q3. The device has two separate clock inputs, CPu and CPd. The clock pulses are applied to CPd in order to decrement the value to zero. To permit the cascading of

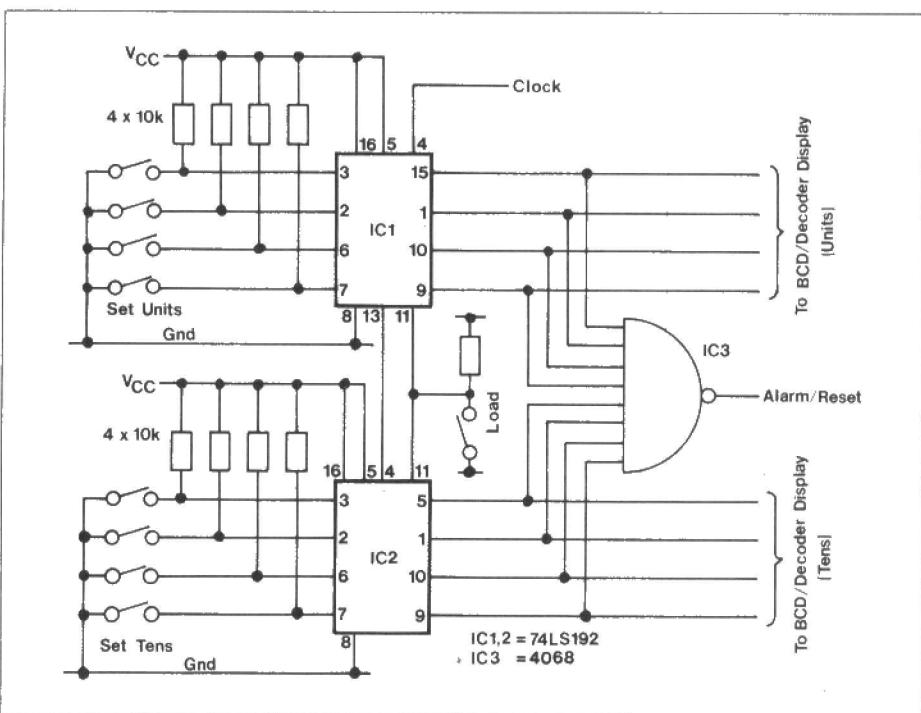


Figure 6. Design using up/down counters

such counters two further pins provide a 'carry out', TC<sub>U</sub> when counting up and TC<sub>D</sub> for counting down. Pin 14, MR, provides the usual Reset to zero facility. The values for loading into the counters are shown being presented by simple switches, such as a bank of eight DIP switches. With a little ingenuity you would see that these could well be replaced by a couple of ordinary BCD counters clocked by another oscillator, or from a higher frequency in a divider chain. These would be operated by just two push switches to set the values, but since they would also need some sort of display, or share a single display, this represents an unnecessary escalation of complexity for demonstration purposes.

As given, the design will count up to 99 seconds, and longer times can be achieved by adding another stage; under these circumstances it is easier to keep the counting in seconds, say up to 999 seconds, (16 mins. 39 secs.), rather than again adding the complication of counting minutes and seconds. The arrival at zero of the outputs from each counter can then be detected by applying them to an eight input NAND gate. When each input has attained a logic low state the output will go high, and may be used to reset the counters, inhibit the clock or initiate an alarm circuit.

The second option is shown in Figure 7. This is somewhat similar to the first, but here the time value is held by a pair of special BCD encoded thumbwheel edge switches. Reference to the Maplin catalogue will give a good idea of what these look like for those unfamiliar with them. As before, the same effect can be obtained with ordinary switches, but the advantage of this type is that it displays the value set and it is more convenient for connection directly to logic gates. For

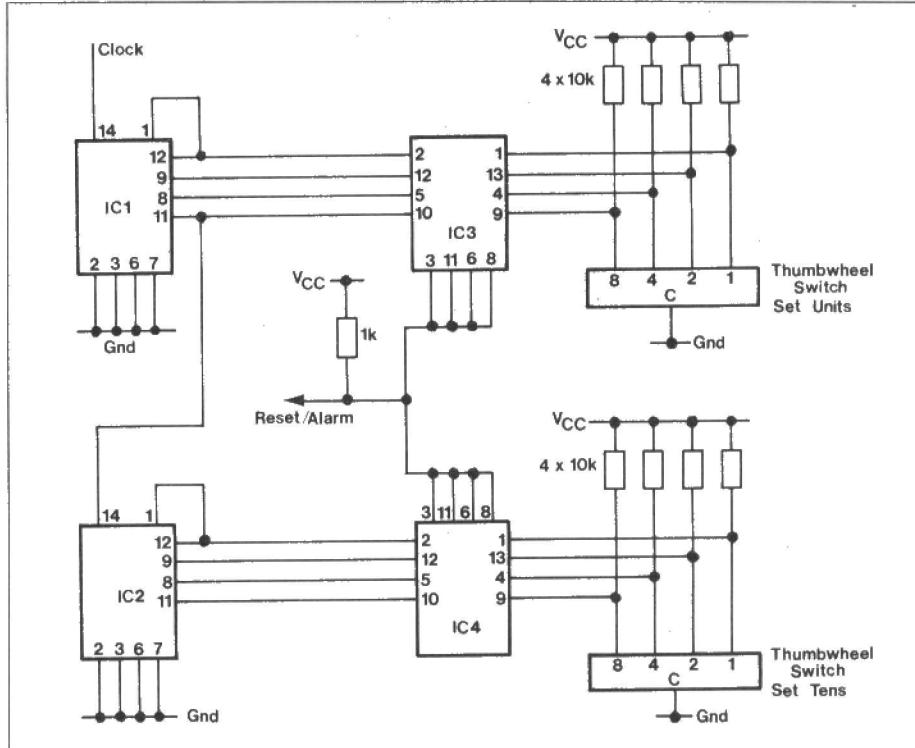


Figure 7. Thumbwheel design

this approach a simple BCD counter such as the TTL 7490 may be used, as here, or the two contained in the single 4518 CMOS package. The other main requirement is for some form of 'comparator' to produce an output when the value set by the thumbwheel switches and the counters is the same. Again, there are several ways of achieving the same end, from the use of special comparator chips to an implementation in combinational logic. The method shown in the design uses a pair of open collector Exclusive OR gate packages, an idea taken from one of the earlier articles.

In each of these approaches the BCD decoders and 7-segment displays could be dispensed with altogether, and reliance placed on the value displayed on the edge switches. Alternatively, additional 7-segment displays might be added, one set to indicate the set time and the original to show the lapsed time.

So much for counters and timers, and it is left to you to think of further variations on this theme. Next time we shall be examining the ideas behind multiplexing as well as making a start on the mysteries of the chips associated with microprocessors.

## CORRIGENDA

### Vol. 3 No. 11

**Enlarger Exposure Meter.** Some constructors have been experiencing some difficulty in calibrating and using the Exposure Meter. The problem has been traced to IC1 latching up and creating a false response. All current kits have had IC1 changed but should anyone be in possession of an early kit with this problem, all that is required is to change IC1 from the CA3140 (QH29G), to the CA3130 device (QH28F).

### Vol. 3 No. 11

**Cautious Ni-Cad Charger.** Some constructors have found that charging one single cell or ten cells together has not worked properly. The failure to charge one cell properly was caused by the limits of the common mode input ratio of the op-amps IC6 and IC7 being exceeded unless said devices were non-typical examples meeting the highest standards of the specifications laid down

during manufacture. To bring the devices within their guaranteed minimum working range, remove the end of R8 which connects to the positive supply rail and the anode of D2 and C1, and connect to the cathode of D2 and the positive battery charging output socket (+Ve). This can be done by carefully cutting away the PCB track around the pad of R8, and then linking same with a short piece of insulated wire to the pad at the cathode of D2.

If you need to charge 10 cells at once then it is necessary to change T1 for LY03D with the secondaries in parallel. After this change, if you then also wish to charge single cells, you will need to provide more heatsinking for TR2.

### Vol. 4 No. 13

**New products, transformer kits.** In the case of the 20, 50 and 100VA transformer kits the core material has been described as 'soft iron', which is incorrect. The material used in modern transformers is generally known as 'electrical steel'.

## TOP TWENTY KITS

THIS LAST MONTH	DESCRIPTION OF KIT	ORDER CODE	KIT PRICE	DETAILS IN PROJECT BOOK
1. (1)	75W Mosfet Amplifier	LW51F	£15.95	Best of E&MM
2. (4)	Partylite	LW93B	£10.95	Best of E&MM
3. (-)	TDA7000 Radio	LK32K	£10.95	9 XA09K
4. (3)	Car Burglar Alarm	LW78K	£7.49	4 XA04E
5. (-)	Break Contact	LW59P	£2.85	2 XA02C
6. (12)	ZX81 I/O Port	LW76H	£10.49	4 XA04E
7. (6)	8W Amplifier	LW36P	£4.95	Catalogue
8. (8)	Light Pen	LK51F	£10.95	12 XA12N
9. (7)	Ultrasonic Intruder Detector	LW83E	£10.95	4 XA04E
10. (17)	Computadrum	LK52G	£9.95	12 XA12N
11. (9)	Synton Drum Synthesiser	LW86T	£12.95	Best of E&MM
12. (10)	Logic Probe	LK13P	£10.95	8 XA08J
Case also available: FJ37S Price £1.48				
13. (11)	Harmony Generator	LW91Y	£17.95	Best of E&MM
14. (5)	Modem	LW99H	£49.95	5 XA05F
Case also available: YK62S Price £10.95				
15. (-)	Musical Announcer	LK57M	£13.50	13 XA13P
16. (-)	VIC20 RS232 I/F	LK11M	£9.45	7 XA07H
17. (15)	Spectrum RS232 I/F	LK21X	£21.50	8 XA08J
18. (-)	Servo & Driver Module	LK45Y	£10.95	11 XA11M
19. (19)	50W Amplifier	LW35Q	£15.95	Catalogue
20. (-)	Ultrasonic Interface	LW84F	£2.95	4 XA04E

Over 80 other kits also available. All kits supplied with instructions.

The descriptions above are necessarily short. Please ensure you know exactly what the kit is and what it comprises before ordering, by checking the appropriate Project Book mentioned in the list above.

# 4-CHANNEL PWM CONTROLLER

- ★ 4-Channel PWM (0-5ms) Outputs
- ★ Internal or External Synchronisation
- ★ High or Low Strobe Input
- ★ Compatible with many Model Servo and Motor Drive Systems

by Dave Goodman

This module allows the use of either mechanical switching or computer control for developing four 20ms frame, 0-5ms+V PWM channel outputs suitable for model servo mechanisms and motor control systems. Mechanisms and motor systems are available from MAPLIN and find applications in Robotics, Model Kits or Educational Demonstrations.

## Circuit Description

Eight data inputs are used to drive the module of which the first six (D0-D5) determine the output PWM and the remaining two select 1 of the 4 available channels. IC1 buffers and latches information presented on D0-D7. Latching may be accomplished synchronously by applying a positive or negative strobe pulse to the CS input or asynchronously whereupon internal clock signals are used. A 3-position switch, S1, is set according to requirements as follows:-

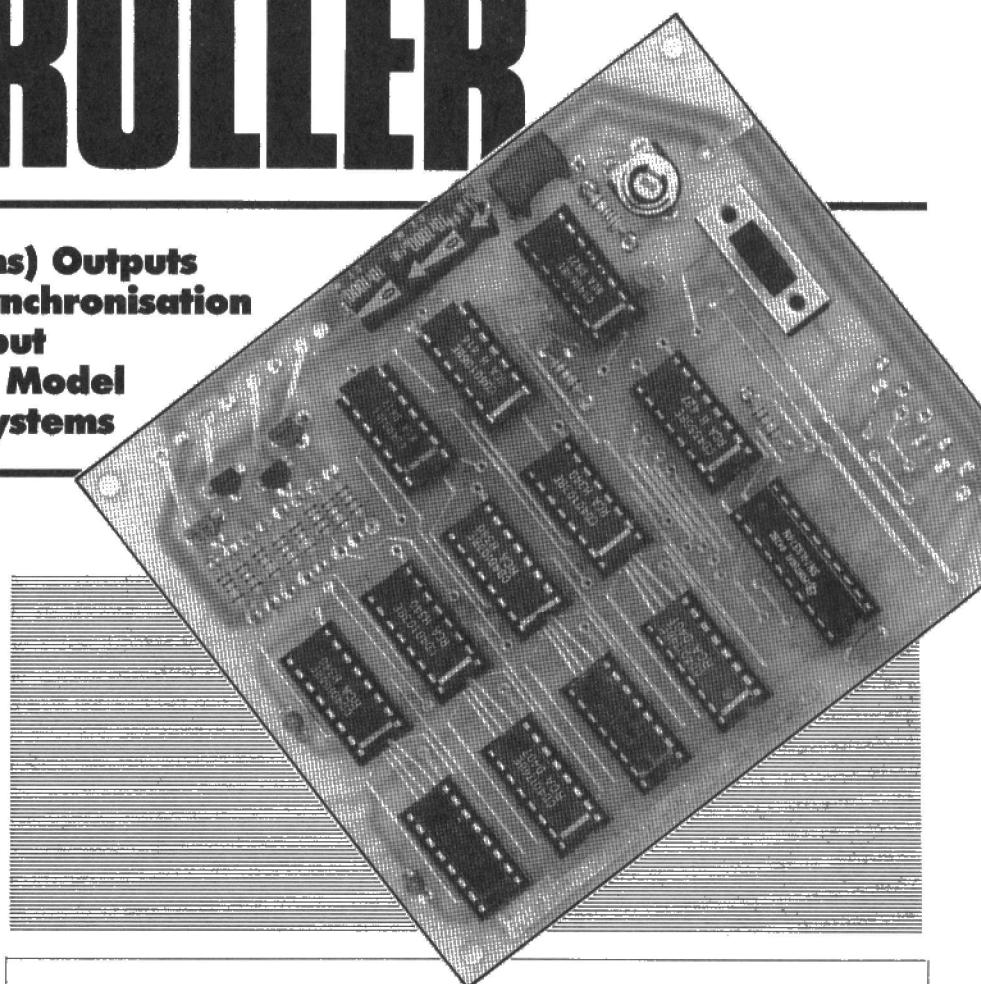
Table 1

S1 position	Effect
B	+ve going CS Pulse
C	-ve going CS Pulse
A	Internal Clock

For descriptive purposes, assume S1 position 'A' (clocked mode) selected, D0-D5 all high (+5V), and D6, D7 both low (0V). See Table 2.

From Table 2, it can be seen that with both D6 and D7 low, channel 1 is selected. Further data input codes (0 to 63) that maintain D6 and D7 low will therefore be directed to channel 1 only. The control code range for channel 1 is then 0 to 63 (decimal).

IC3 is the clock-oscillator running at 409.6kHz, and C2 and RV1 determine the



Channel	PWM Output		
No.	Data (D7,D6)	Code	Data (D5-D0) Input Code
1	0 0	+0	0-63 0 to 63
2	0 1	+64	0-63 64 to 127
3	1 0	+128	0-63 128 to 191
4	1 1	+192	0-63 192 to 255

Channel codes 0,64,128,192 = minimum (zero) output.  
Channel codes 63,127,191,255 = maximum (5mS) output.

Table 2

clock rate. This IC also internally divides the clock through several stages and one of these stages ( $\div 16$ ) produces a 25.6kHz signal to IC4a. S1 is set to position 'A', thus IC4a output strobes IC2 enable input at this rate. IC2 is a dual 1 of 4 decoder with two data inputs (D6 and D7) connected to pins 2 and 3 on one half of the IC. Assuming a 39 $\mu$ s clock pulse has made a transition from high (+5V) to low (0V), then data in IC1 will be latched from pin 11, pins 2 and 3 on IC2 will be low and the pin 1 enable input will be active. One of four outputs from IC2 will go low and for the 00 code, pin 4 becomes active. Of course, during the previous latching or clock period, data bus D0 to D5 will hold valid information and as all lines high is assumed for this example, then the code

on the common bus will be 63. IC6 to IC9 all receive the same code, so some method of selecting the correct channel has to be instigated. For this description, IC6 pin 6 goes low (decoded output from IC2); the data bus is then clocked and latched into this IC only. IC10 (and 11 to 13) is an 8-stage, presettable, synchronous down counter configured as a divide by 'n' ( $\div 1$  to 255) device. Latched data from IC6 is presented to IC10 on all six data input lines. A fast synchronising pulse (see Figure 3) from IC4b presets the divider and a gated 12.8kHz clock signal is applied from IC5a, which starts the new count down period. In effect, pin 14 O/P which is normally low (or 0V) is pulsed high for countdown periods determined by all six latched data inputs.

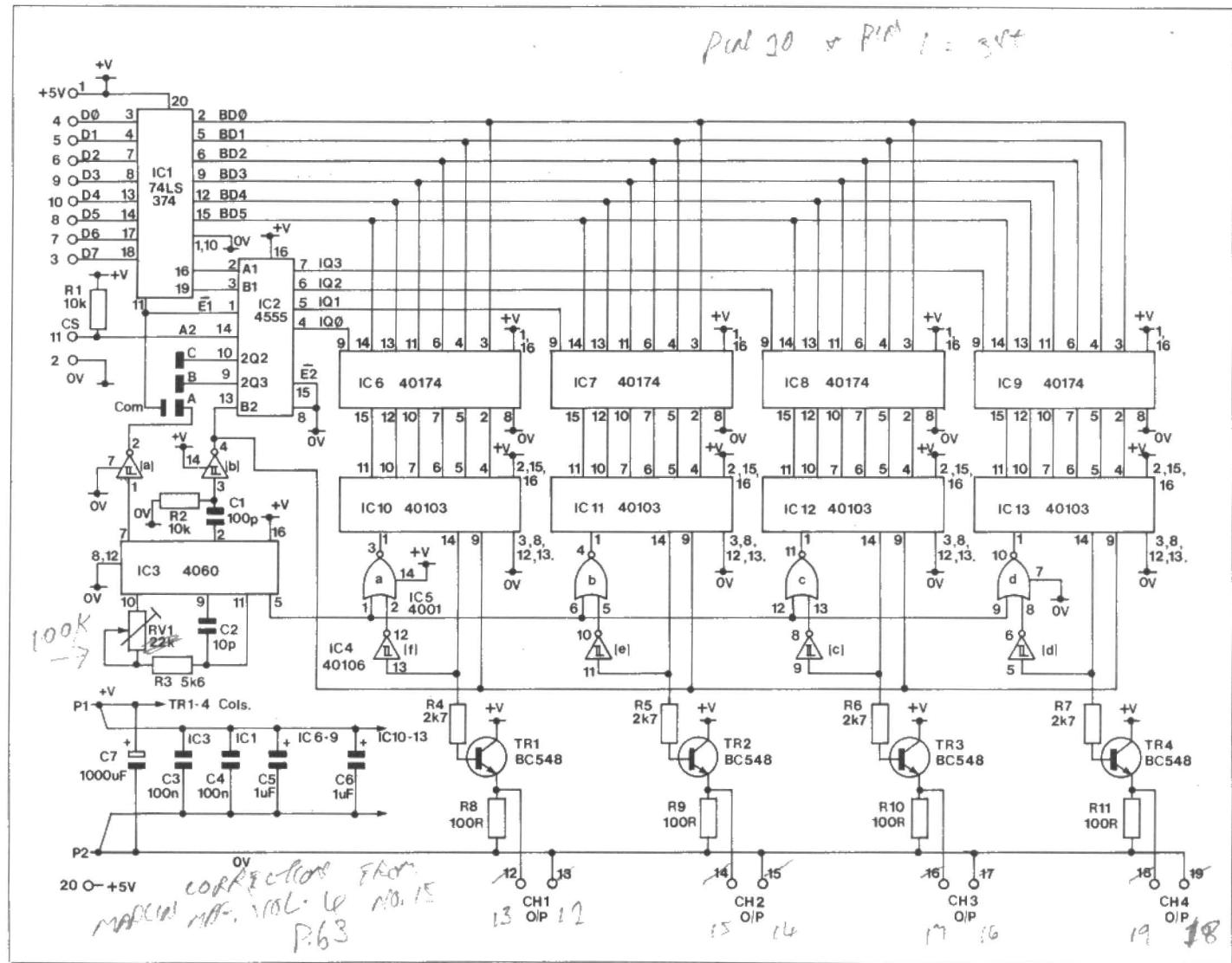


Figure 1. Circuit Diagram

After countdown, the output level will return to 0V and this is repeated 50 times per second. Data to the latched inputs can be changed at any time and on any of the four channels decoded by IC2. Final output drive comes from emitter follower buffers (TR1 - TR4) which will drive into low impedance devices suitable for use on 20ms PWM, such as model servos and small motor drive modules.

## Construction

With reference to the Parts List and Figure 2, identify and insert resistors R1 and R2, R4 to R7, R8 to R11 and R3. Fit components into the PCB from the legend side only, and ensure every one lies flat on the board.

Next, mount the IC sockets; IC1 is 20-pin type, IC's 4 and 5 are 14-pin types and the remaining ten are 16 pin sockets. After inserting a socket, bend a few terminals over underneath on the track side, so as to help prevent it from falling out during soldering. Fit the disc capacitors C3 and C4, and the small ceramic capacitor C1 and the silver mica C2. Be careful not to damage their leads by excessive bending or pulling. Fit both tantalum capacitors C5 and C6. One lead will be found to be longer than the other, and also marked with a small + sign. Insert this lead into the hole in the PCB designated also by a + sign. Mount all 4

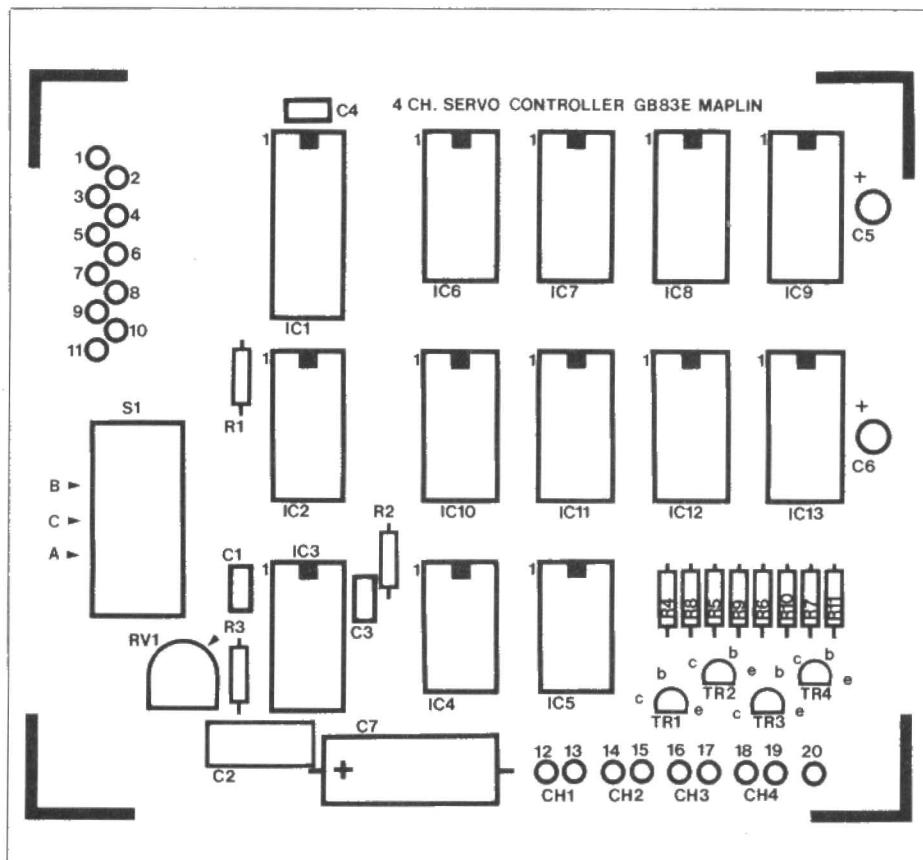


Figure 2. PCB Overlay

transistors TR1 – TR4. For orientation purposes, align these components with the legend, pushing them down to approximately 5mm clearance above the board. Insert preset RV1. Insert the Veropins into the board at the 20 positions marked on the legend. Turn the module over and solder all terminals correctly in position, being careful not to introduce poor joints or short circuits in the process. Finally, insert S1 and C7. This capacitor is polarised, and only the negative terminal is marked on the component body. Do not fit this lead into the hole marked with a + sign! Now solder all remaining leads, cut off excess lengths and if a suitable solvent is available, clean flux and splashes from the tracks. Re-inspect all work done and when satisfied that everything is correct, proceed with testing operations.

## Testing

For testing, you will require a multimeter, 5V power supply, an oscilloscope, a non-metallic trimming tool and a length of wire.

Before inserting any IC's into their sockets, connect the PSU, with +5V to pin 1 and 0V to pin 2. Switch on the supply and, with the meter, take a voltage reading across C7. This, of course, should read 5V with the correct polarity. If the reading is negative, then the supply may be connected to the wrong pins! Switch off and insert all IC's into their respective sockets.

Set the RV1 wiper position to the arrow on the legend which is at approximately 2 o'clock next to R3. Set S1 to central position C and connect the 'scope probe earth to C7 negative end.

Re-apply power and take a 'scope probe measurement on IC3, pin 2. You will see a 5V square wave signal which can be changed in frequency by moving RV1. Adjust RV1 wiper to give a 50Hz 20ms display, as the signal waveform shown in Figure 3. Alternatively, a frequency counter could be used instead of an oscilloscope for setting the clock frequency. Switch off power and with the wire, connect data input pins 7 and 3 only (D6, D7) to 0V pin 2. Re-apply power and take a 'scope reading on channel 1 output pin 12. There will again be a 20ms period signal displayed at an amplitude of 3.5 to 4V. The +V or 'MARK' pulse width should be 5ms duration and the off or 'SPACE' width 15ms. If any combination of D0 to D5, input pins 4 to 6 and 8 to 10, are now connected to 0V, the MARK/SPACE ratio can be changed accordingly from zero up to a maximum of 8ms. Most model servos operate over a 'MARK' pulse width range of 0.5ms to 1.5ms and the developed PWM signal from the module should be suitable for most applications.

Now remove the 0V connection from D6 (pin 7) and leave D7 (pin 3) connected. Further grounding of data inputs D0 to D5 will not affect the last channel 1 output signal. Place the 'scope probe on channel 2, pin 14, and check for a 5ms PWM signal output as before. Connect D6, pin 7, to 0V again and this

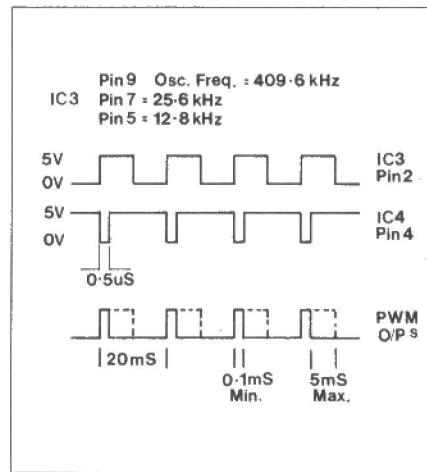
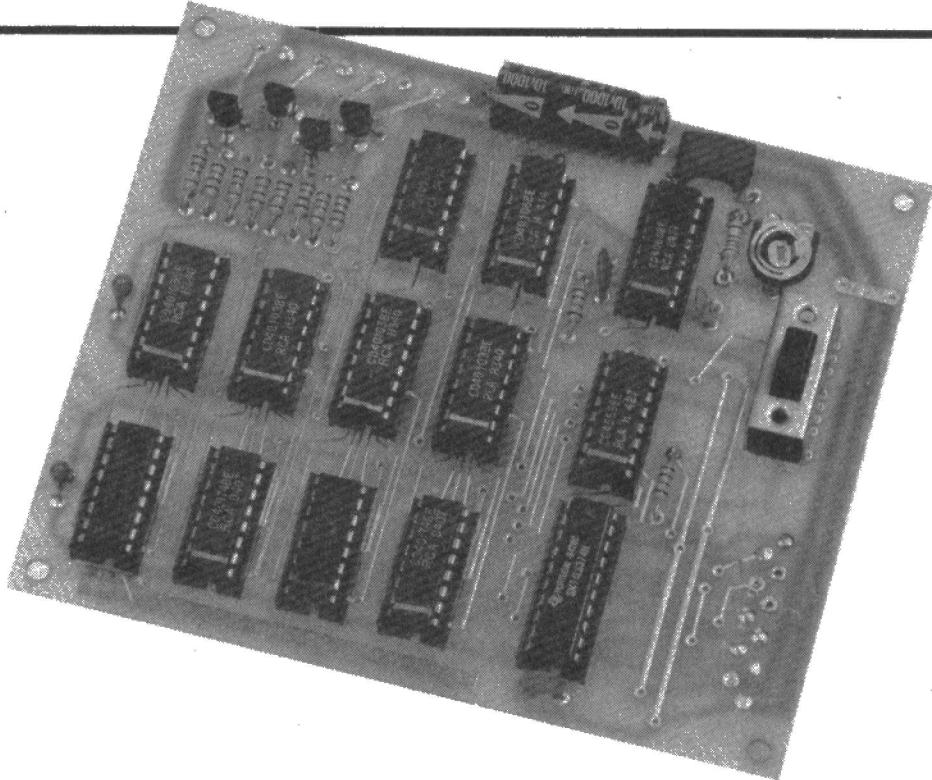


Figure 3. Signal Waveforms

time remove the 0V connection to D7, pin 3. Check channel 3, pin 16, PWM output and finally remove all D0 to 7 connections to 0V, and check channel 4, pin 18, PWM output.

By this method of selecting channels 1 to 4 from D6 and D7, one channel at a time is accessed and PWM data codes affect only that channel selected. Other channels remain latched to the last data code entered and can only be re-accessed by setting the correct D6, 7 code as Table 2.

## Servo Testing

As an alternative to testing with an oscilloscope, small model control servos can be used. These are connected to 0V

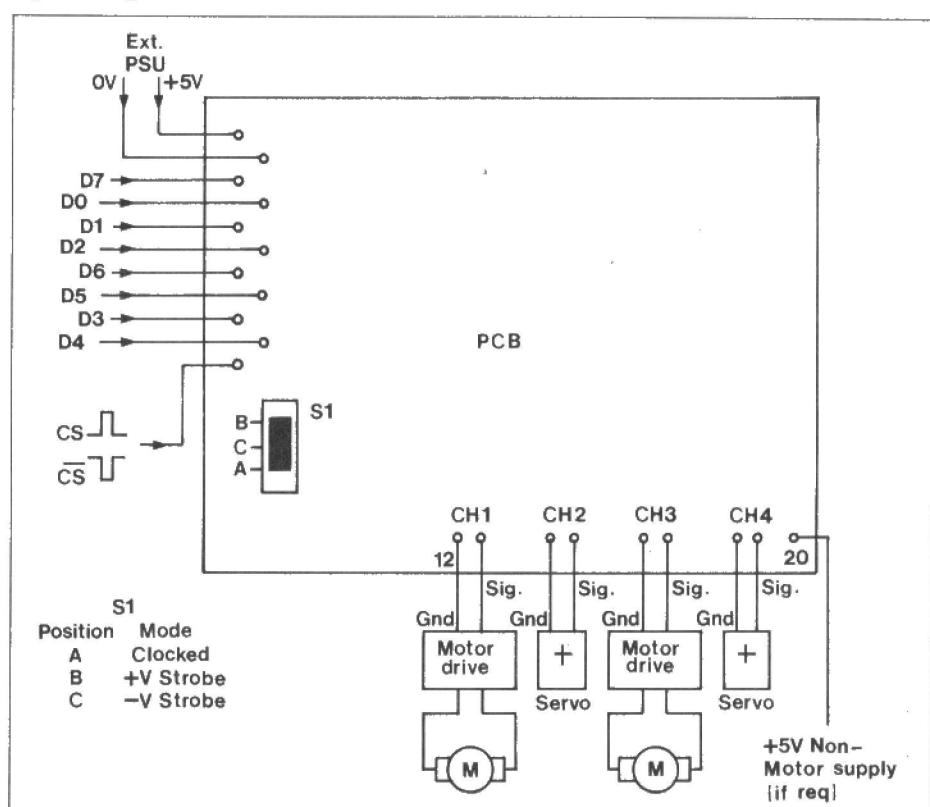


Figure 4. Wiring Diagram

and +5V and their PWM signal input line connected to channels 1 to 4 outputs in turn. Two factors must be considered before attempting this method. Firstly the power supply should have at least 1A at 5V capability, mostly for driving the servo motor, as the module running current is only 40mA. And secondly, problems may be encountered when generating PWM signals well outside of the servo's range. As a guide to approximate minimum and maximum pulse width outputs, use D0 to D5 codes 5 and 43 respectively. Data code 5 corresponds to 0.5ms pulse period and code 43 gives 1.5ms. With this in mind, the

testing procedure can be followed using these two codes on all channels. Combinations of D6, code 64, and D7, code 128, will of course need to be added to the PWM codes as in Table 2.

## Using The Module

Mechanical or electronic switching can be connected to data inputs for controlling channel outputs. Without connections to these lines, channel 4 is automatically selected as D6 and D7, and D0 to D5 are high (TTL inputs). This means that changes made to D0 - D5 affect channel 4 only. For this type of switching, S1 mode C should be used

as data is then latched in by the internal clock. For connection to computer data buses, S1 modes A and B should be used, unless data is passed by a latching interface, whereupon mode C could be used again. If it is intended to connect D0 to D7 directly to a microdata bus, then a select strobe control line must be used. The strobe pulse may be either active positive or negative going, but must be greater than 0.5μs period (typically 1μs). Table 1 shows S1 positions for different CS conditions. Data should be presented to IC1 before the strobe pulse is active and should be stable for this period. Otherwise, pulse output jitter will occur.

## 4-CHANNEL PWM CONTROLLER PARTS LIST

### RESISTORS: All 0.4W 1% Metal Film

R1,2	10k
R3	5k6
R4-7	2k7
R8-11	100Ω
RV1	22k Hor. Sub-min Preset

### CAPACITORS

C1	100pF Ceramic
C2	10pF 1% Mica
C3,4	100nF Mini-disc
C5,6	1μF 35V Tantalum
C7	1000μF 10V Axial Electrolytic

### SEMICONDUCTORS

TR1-4	BC548
IC1	74LS374
IC2	4555BE

IC3	4060BE	1	(QW40T)
IC4	40106BE	1	(QW64U)
IC5	4001BE	1	(QX01B)
IC6-9	40174BE	4	(QW73Q)
IC10-13	40103BE	4	(QW61R)
MISCELLANEOUS			
S1	Printed Circuit Board	1	(GB83E)
	4-pole 3-way slide switch	1	(FH38R)
	14 DIL socket	2	(BL18U)
	16 DIL socket	10	(BL19V)
	20 DIL socket	1	(HQ77)
	Pin 2145	1 pkt	(FL24B)

A kit of the above parts is available.

Order As LK61R (4Ch Servo Cntrlr Kt) £21.95

The following is also available separately, but does not appear in the 1985 catalogue:

4-Channel Servo Controller PCB Order As GB83E Price £7.95

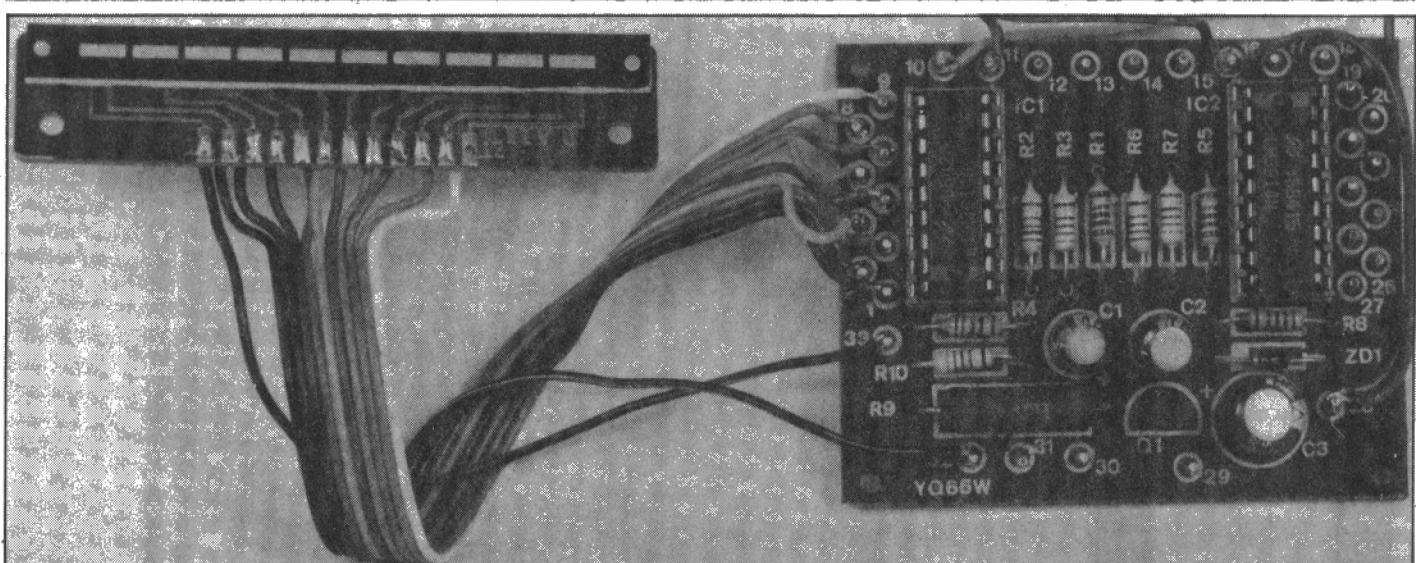
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# DISPLAY DRIVER MODULE

by Dave Goodman

- ★ Many Types of Display can be Driven
- ★ Choice of Driver Chips
- ★ Flashing Option
- ★ Easy to Build

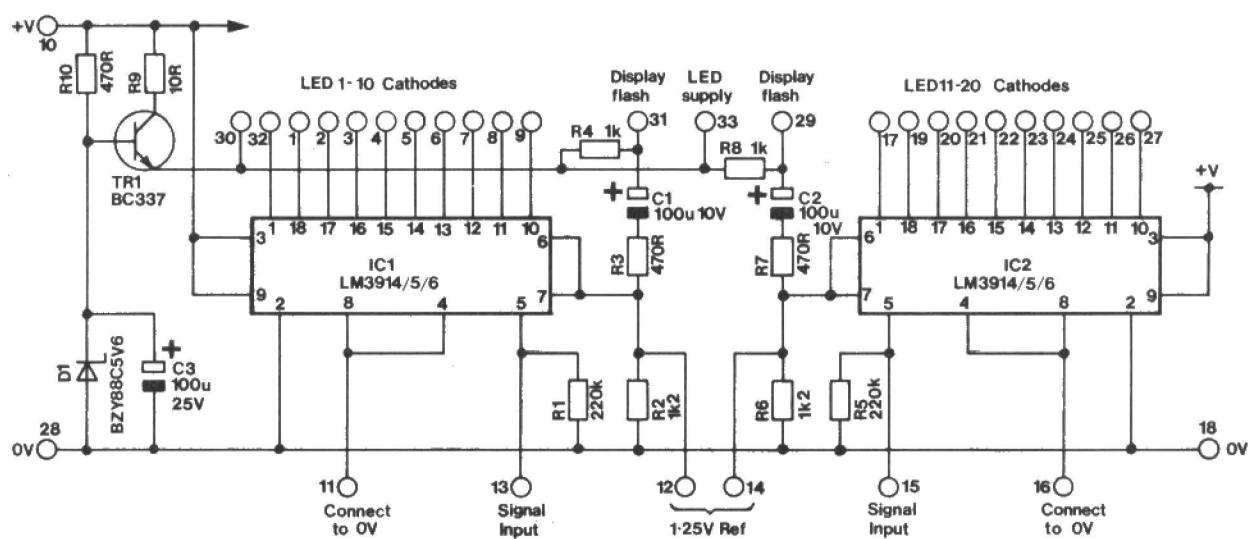


Figure 1. Circuit diagram

Many projects built by the Home Constructor require a LED display to give an indication or show a response to a set of circumstances. This article will describe a module which will drive up to 20 LED's and also show how to make those LED's flash on and off. Many different types of LED display can be used with this module and in addition to this, different driver chips can be used to give varying displays.

A dual display driver PCB for the LM3914-16 range of display driver IC's can be used for single DOT or sequential BAR mode control of the 20 LED's. Display brightness is adjustable and FLASH can be determined from any desired LED position. Three types of IC are available from MAPLIN's range which have identical operating characteristics but offer different response of input voltage to display output. Figure 5 is a graphic representation which shows the response curves of these IC's in BAR mode. Each of the LED's (1 to 10) are sequentially operated in turn as the input DC voltage is increased from approximately 50mV to 1.3V, and for the LM3915 a linear scale can be observed. For a logarithmic scale, the LM3915 is chosen, which increments each LED in 3dB steps and the LM3916 is suitable for VU displays.

## Circuit Operation

IC1 (2) requires very little external components as all LED controlling elements are internal to the IC (see figure 7). Ten comparator output stages control each LED via an internal resistor ladder network, referenced to a 1.25V constant voltage source, and an increasing signal voltage applied to the high impedance voltage follower, switches each comparator in turn. Figure 1 shows the 5V regulator: R10, D1 and TR1, which feeds each anode of LED's 1 to 20. Either single LED's or common anode 10 LED displays can be used here, and R2 determines LED current or brightness. Reducing the value of R2 increases LED current (and vice-versa) and with the recommended value of 1k2, approximately 10mA flows through each LED. PCB pins 4 and 8

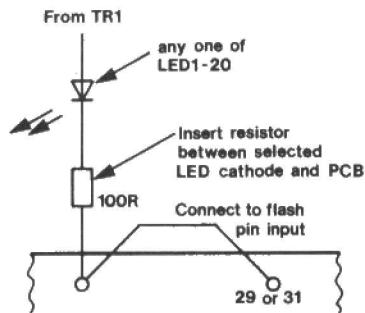


Figure 4. Connection for flashing mode

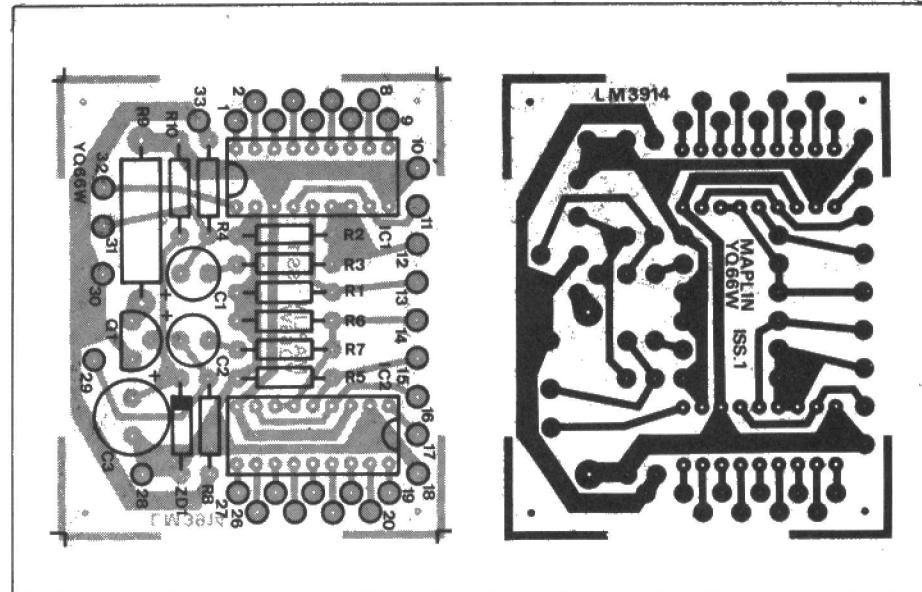


Figure 2. PCB track layout and overlay

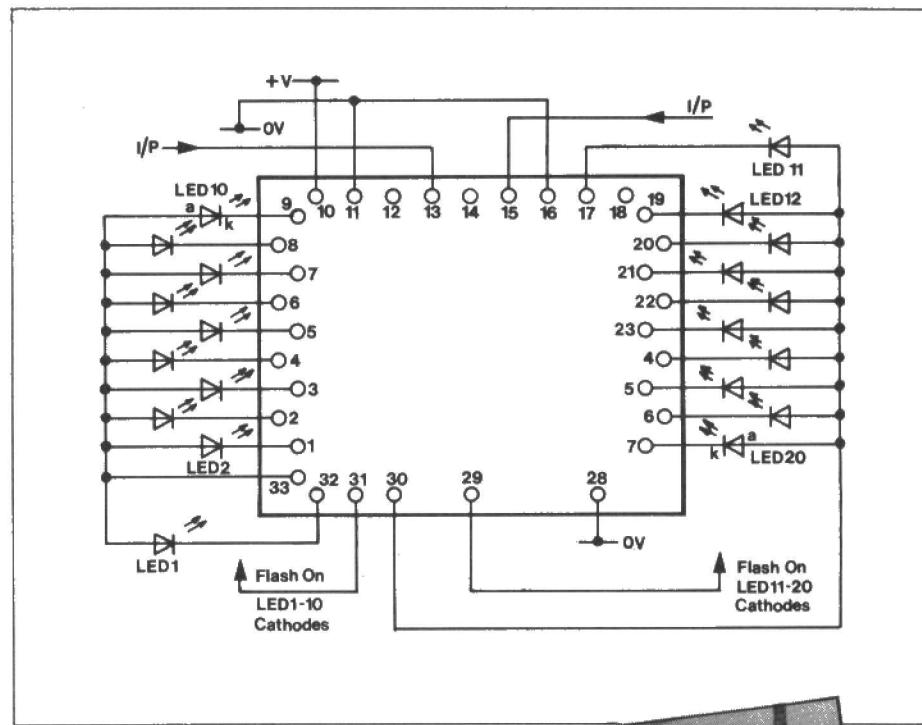
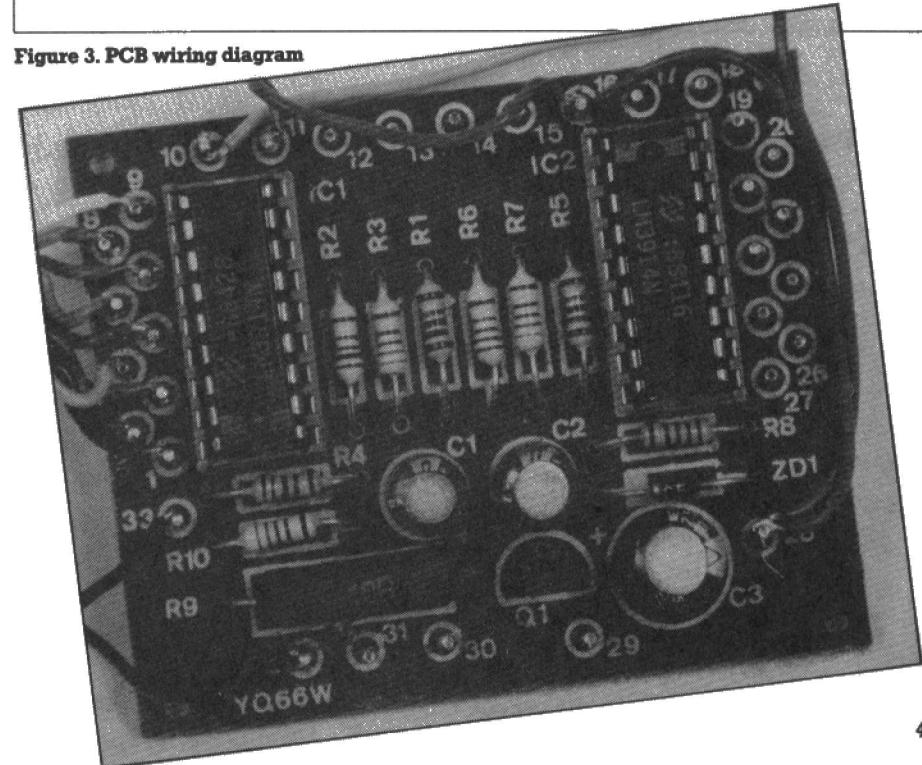


Figure 3. PCB wiring diagram



should be connected to 0V, although these inputs could be referenced positively above ground, thus changing the point with which input signals start to switch the LED's. LED 1 output will normally be active with input signals = +0.1V when pin 11 is at 0V. Connecting pin 11 via a resistor to 0V raises the comparator threshold so that a higher input voltage will be required to drive the display. Figure 8 shows the appropriate connections to those pins and Table 1 indicates resistance values and the approximate minimum input voltage required to operate the first LED of the display.

## **Flashing**

Flash input pin 31 (29) can be connected to any one (only) of LED's 1 to 10 (11 to 20) as shown in Figure 4. It is important to connect a  $100\Omega$  resistor in series with the chosen LED otherwise insufficient discharge current for C1 (C2) is developed. For example, connecting LED 10 via a  $100\Omega$  resistor to pin 9 on the PCB and connecting pin 9 to pin 31 flash input, will cause all ten LED's to flash twice a second and could signify display over voltage in a voltmeter project.

**PCB Connections**

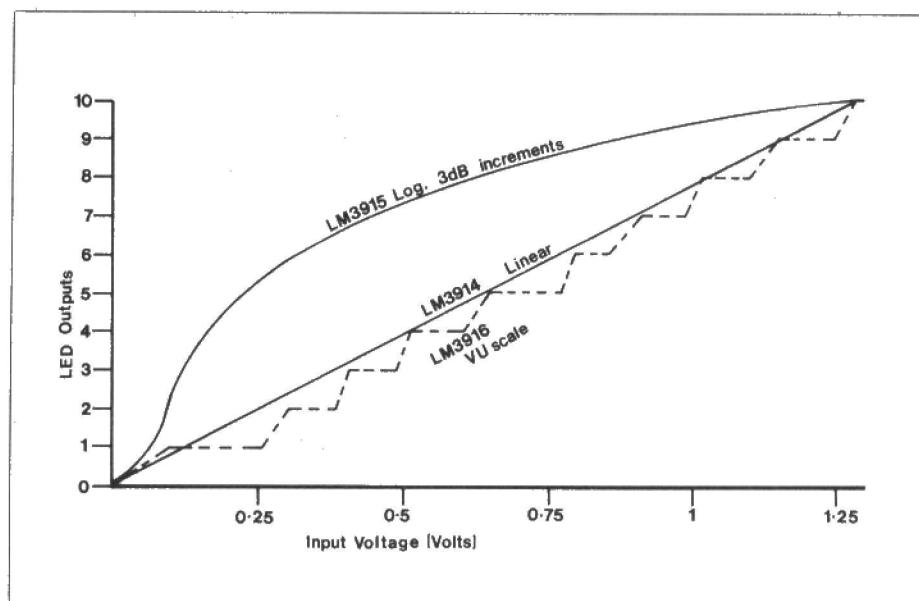
Figure 3 shows external connections to the module. A power supply of 5 to 15V is required with 150mA current handling capability. Pins 1 to 9 and 33 are LED cathode connections to IC1 and pin 30 is the common anode +5V supply. Pin 31 is the flash input and can be wired to any one of the 10 pins previously mentioned. Pins 18 and 28 are common 0V connections and pin 10, the 5 to 15V supply. Pin 12 has a 1.25V reference output voltage available, pin 13 is the signal input terminal and pin 11 should be connected either directly to 0V or via a resistor (see Figure 8). Corresponding pins associated with IC2 perform the same functions as their counterparts on IC1 and operation of both sections is identical.

## **LED Displays**

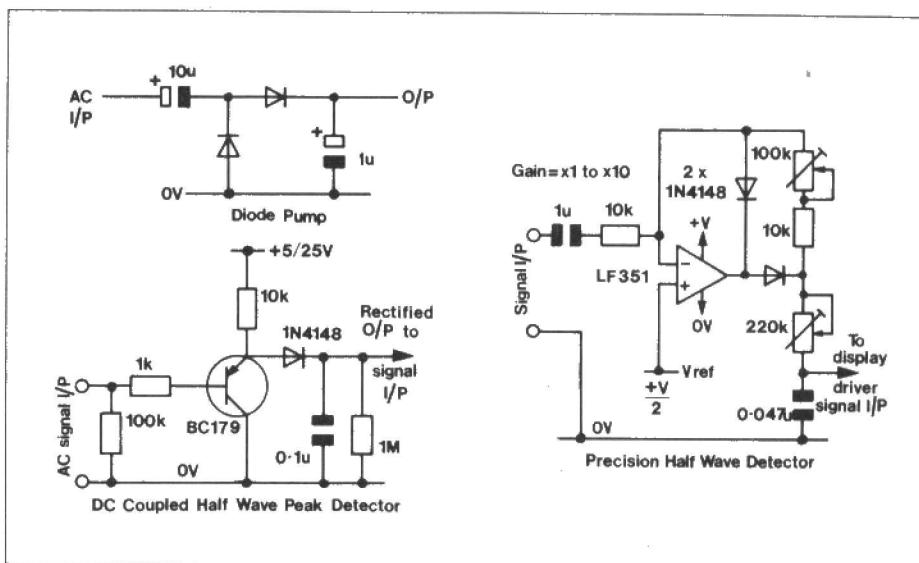
Figure 9 shows five of the most useful displays available from MAPLIN's Catalogue, along with terminal notations. The Parts List has stock codes of these components if required. These displays are suitable for use as voltmeter indicators, alarm flashers, sensor indicators, amplifier power level meters, graphic equaliser response, VU meters and the module could be used to replace panel meters in these applications.

## **Operation**

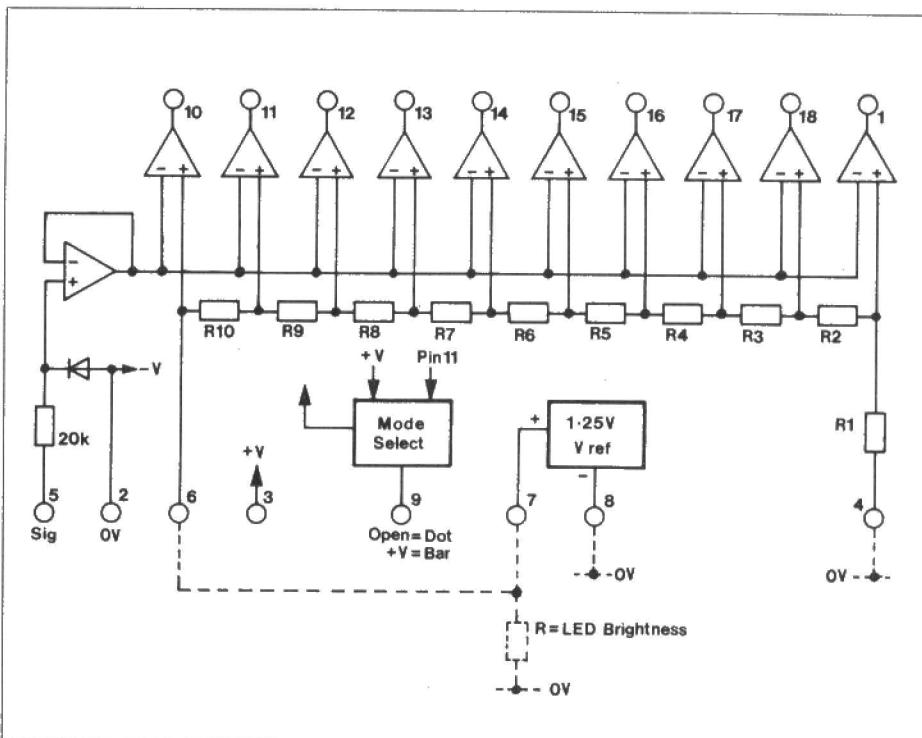
So far, all input specifications refer to positive DC signals and not to AC signals. Sinewaves can be fed directly to the signal input for display, but problems may arise when calculating average or peak levels, or the amount of dampening required to ensure a readable display.



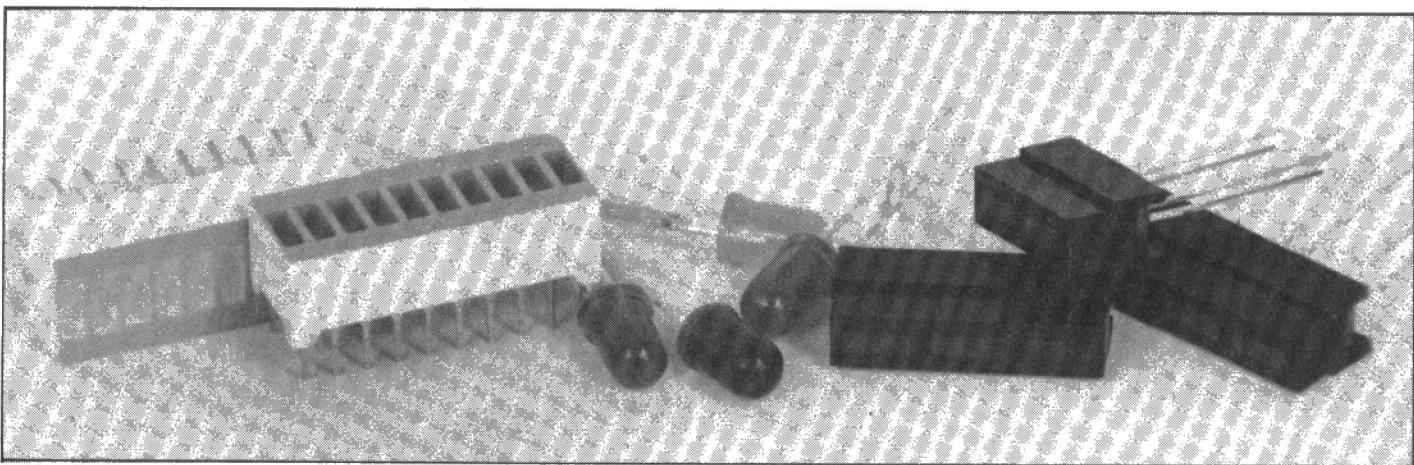
**Figure 5.** IC response curves



**Figure 6. Input AC detector circuits**



**Figure 7.** Internal circuit of LM3914/5/6



Some example circuits are given in Figure 6 which convert AC signals to DC voltages suitable for driving the module. The diode pump is the simplest to use, although its input impedance is low, and diode forward voltage drop must be considered. A capacitor at the output damps the display for a slow response reading and values are chosen accordingly.

Absolute maximum input signal voltages should be kept below 35V peak and wiring from LED's to module must be as short as possible to avoid HF noise radiation causing interference in audio equipment. DOT or single LED mode is simply produced by not inserting pin 9 on IC1 (2) into the PCB and is left floating.

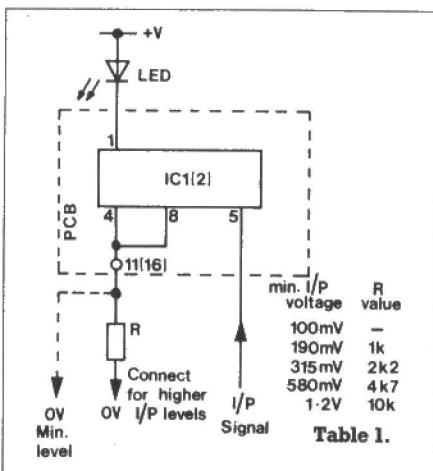


Figure 8. Input level reference

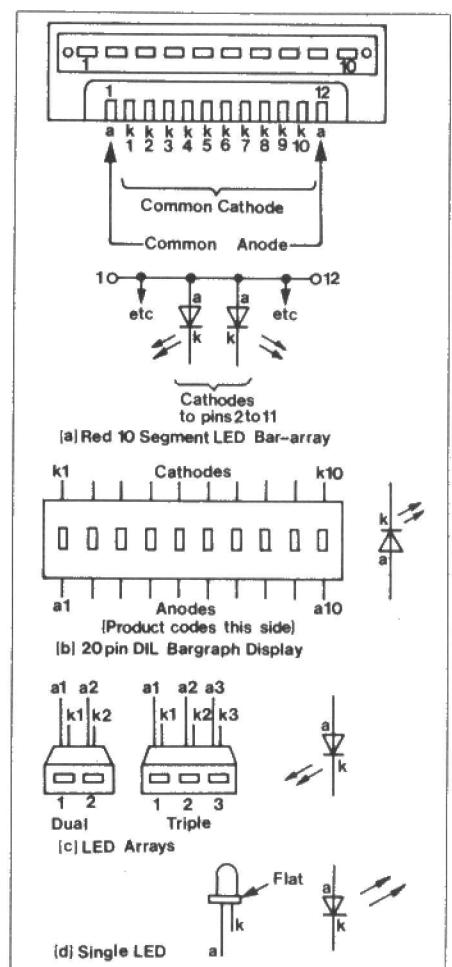
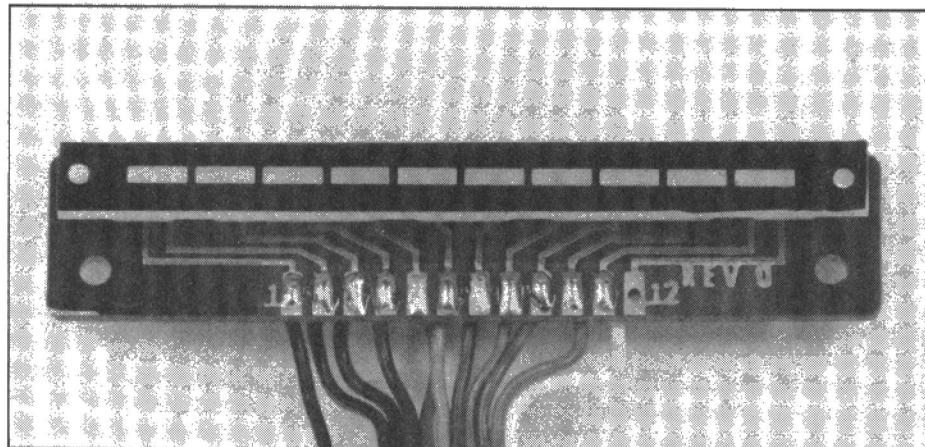


Figure 9. Pin connections of various displays

## PARTS LIST FOR DISPLAY DRIVER

RESISTORS: All 0.4W 1% Metal Film unless specified

R1,5	220k	2	(M220K)
R2,6	1k2	2	(M1K2)
R3,7,10	470Ω	3	(M470R)
R4,8	1k	2	(M1K)
R9	10Ω 3W Wirewound	1	(W10R)

### CAPACITORS

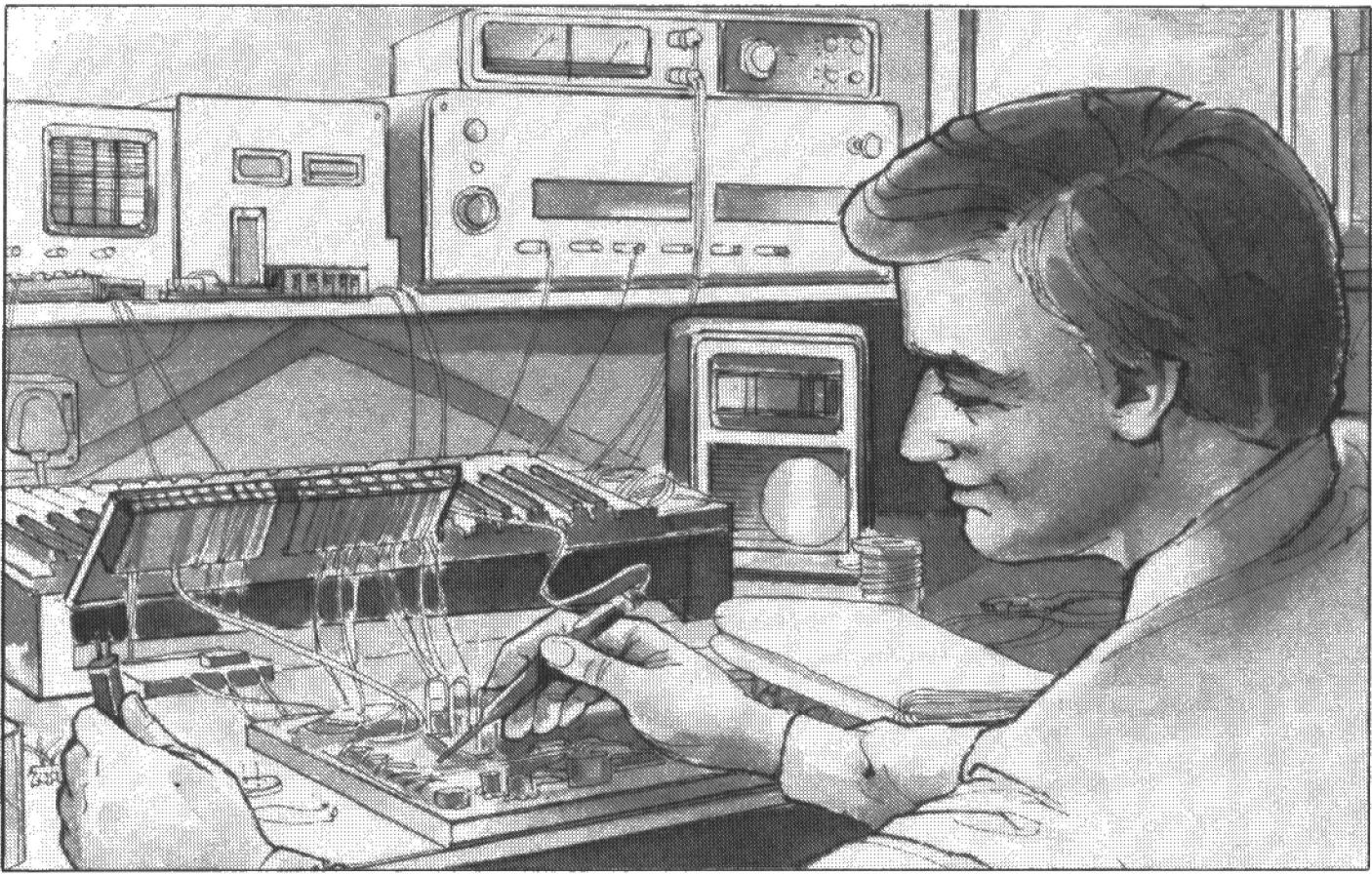
C1,2	100μF 10V PC Electrolytic	2	(FF10L)
C3	100μF 25V PC Electrolytic	1	(FF11M)

### SEMICONDUCTORS

ZD1	BZY88CSV6	1	(QH08J)
TR1	BC337	1	(OB68Y)
IC1,2	LM3914 or LM3915 or LM3916	2	(WO41U) (YY96E) (YY97F)

### MISCELLANEOUS

Printed Circuit Board	1	(YQ66W)
Veropin 2145	1 pkt	(FL24B)
DIL Socket 18-pin	2	(HQ76H)
Red 10 Segment Bargraph	As req	(YH76H)
Red Bargraph Display	As req	(BY65V)
Green Bargraph Display	As req	(YG33L)
Dual LED Array Red	As req	(YH77I)
Tri LED Array Red	As req	(YH78K)
Dual LED Array Green	As req	(VH79L)
Tri LED Array Green	As req	(YH80B)
Dual LED Array Yellow	As req	(YH81C)
Tri LED Array Yellow	As req	(YH82D)
LED Red	As req	(WL27E)
LED Green	As req	(WL28F)
LED Orange	As req	(WL29G)
LED Yellow	As req	(WL30H)



# PROJECT FAULT FINDING

by Robert Penfold Part Two

In the first article of this series we considered some very basic methods of fault finding which require little technical knowledge or test equipment, but are relatively slow and inefficient. In this second article of the series we will look at some fault finding methods which are more methodical and require a little more in the way of technical knowledge, but are still comfortably within the capabilities of most electronics enthusiasts.

## Initial Checks

It is usually stated in fault finding books and articles that the first check is to make sure that the supply is reaching the circuit. All of us from time to time make the silly errors such as forgetting to switch on or omitting the battery, and faults with on/off switches and battery connectors are not rare. Checking that the supply is present is therefore a logical first step. However, it might be as well to first check the supply current rather than the voltage. This is due to the fact that circuit faults can often lead to a rather

high level of current consumption, and this can in turn lead to overheating and the destruction of a component or components in the circuit. Semiconductor devices are particularly at risk. A check of the supply current will reveal an excessive current flow, and if this should be the case you should switch off the equipment at once.

If there is a high current consumption this tends to complicate fault finding since most techniques require power to be applied to the circuit. On the other hand, if the part of the circuit that is causing the excessive current flow can be found, this stage is obviously the likely cause of the malfunction and you are 90% of the way to rectifying the fault. It is definitely not advisable to maintain a current flow to a circuit that is drawing a high current as this could easily result in damage to some of the components, and it could even be dangerous as severely overheated components can literally explode.

It is usually very easy to find the component that is passing the high cur-

rent since a high current flow means a high level of power dissipation, and the generation of a significant amount of heat. Simply touching each component briefly in turn will often reveal that one (or possibly several) of the components is running rather on the warm side, although you should bear in mind that some components, especially highly complex semiconductor devices and power devices, are intended to run at relatively high temperatures.

When an overheated component has been located the cause of the fault might be quite obvious. For example, if an electrolytic supply decoupling or smoothing capacitor is overheating it is quite likely that it has been connected with the wrong polarity, or it might simply have broken down. If a component has broken down you should not automatically assume that the device was faulty from the start. In the case of a smoothing or decoupling capacitor it could just be that the component was not up to specification, as the reliability of this type of component is not generally as good as

that of most other modern components. Alternatively it could be that (say) a voltage regulator has become faulty and the voltage across the capacitor is substantially higher than it should be, resulting in the break down. It would therefore be advisable to replace the capacitor and measure the voltage across it to ensure that it is within the rating of the component. If it should be necessary to repeatedly renew a component this would certainly suggest that there is a fault somewhere else in the circuit which is leading to its failure, or possibly that due to a design fault the component is simply inadequate for the task.

Do not jump to the conclusion that the component which is generating the heat is the faulty one, as this is not necessarily the case. Take the typical relay driver circuit of Figure 1 for instance. If TR1 was to show signs of overheating this would not necessarily mean that it was faulty, and this would in fact be unlikely. An open circuit fault in TR1 would result in no significant current flow, and very little dissipation in the device. Similarly, a closed circuit fault in TR1 would result in the relay being permanently activated, but the voltage developed across TR1 would be very small giving very little dissipation in the device. What would cause a higher than normal dissipation would be if TR1 had

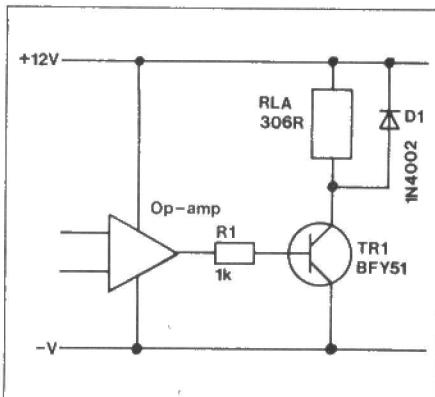


Figure 1. Relay Driver Circuit

an inadequate level of gain (or any fault that produced similar DC conditions), giving a moderate current flow and about half the supply voltage across TR1. Even this would probably not give a very high level of dissipation in TR1, and it would not cause the current consumption of the circuit to be excessive.

A fault such as shorted turns in the relay coil would almost certainly give a high dissipation in TR1. In order to switch hard on and pull its collector voltage down to the 0 volt supply rail it would need to produce a higher collector current than normal due to the lower level of resistance in the relay coil. The base current and current gain of TR1 could well be inadequate to do this, giving much higher than normal collector current and collector voltage. This would give both an excessive dissipation in TR1 and a much higher than normal current consumption for the circuit as a whole. A fault in D1 or connecting it with the wrong polarity would produce very much the



same result.

The point to note here, and it is an important one with any kind of fault finding, is that one should not jump to conclusions. What might at first seem to be the obvious cause of a fault is often not the cause at all, and you should always try to consider things carefully and logically. Another point that is raised here is chain faults. In other words, a fault in one component leading to a fault in another. In this case TR1 might have been perfectly serviceable at switch-on, but the excessive power and current flow could well have lead to it being almost instantly damaged. If the problem proved to be due to (say) D1 being faulty, then it would be quite acceptable to replace this component and then see if TR1 operated properly. In some cases this might not be a very good way of doing things since a fault in a component damaged as a result of the original fault might result in damage to other components in the circuit, including the one that had just been replaced. If there is any possibility of something like this occurring it would obviously be sensible to remove the suspect component from the circuit, test it, and if necessary replace it before switching on and trying out the unit again.

## Voltage Tests

Assuming that some supply current, but not a grossly excessive amount is flowing, the next step is to make some voltage checks. Any multimeter can be used for making voltage checks, but a good quality 20kΩ/volt analogue instrument is the type most often used for general servicing work. As we shall see shortly, a digital multimeter or an electronic instrument having a high input resistance can be more convenient in use, and this fully justifies the extra expense of instruments of this type. Whatever type of multimeter you use I would strongly recommend the type of test prods that can be clipped onto leadout wires as these are much less fiddly in use than the simple 'needle' style

prods. In particular, most voltage checks are made relative to the earth rail, and with the 'clip' type prods the appropriate one can be clipped to any convenient earthing point, leaving the operator to manipulate just one test prod. If necessary it is probably well worthwhile paying extra for a good set of test prods.

You may find that the circuit diagram for the piece of equipment being checked includes some test voltages, but in most cases these will be absent. Even if test voltages are present they may not be as useful as it might at first appear. The voltage levels in circuits are often subject to major variations from one unit to another, making it difficult to be certain what is a correct reading and what is indicative of a fault. Also, finding an incorrect voltage reading does not automatically lead you to the precise fault, and you must gain the ability to interpret test results properly. In most cases further tests will be needed once a faulty voltage reading has been traced before the exact fault can be diagnosed.

With most circuit diagrams not being marked with test voltages to give a rough guide as to what to expect, the ability to make realistic estimates of voltages in the circuit under test is essential. This is really just a matter of applying some basic electronics theory, and it is not the aim of this article to teach the reader this theory. If you do not understand the theory behind the methods described here there are plenty of books which cover this ground, as do some articles in past issues of this magazine.

As an example we will consider the circuit of Figure 2, which is the 'Telephone Amplifier' from the 'Five Easy Pieces' article in Issue 12 of this magazine. This helps to demonstrate several points that apply to many circuits. A circuit description will not be provided here, but can be found in the 'Five Easy Pieces' article (and it would be advisable to consult this if you are not already familiar with this circuit).

As explained earlier, the first voltage check would be to ensure that the supply voltage is getting through to the circuit. In this case the early stages obtain their positive supply rail via a decoupling network and the voltage from earth to the junction of R1, R3, R6, etc. should also be checked. There will be some voltage drop through R8 and the voltage here must be less than battery voltage. However, the value of R8 is very low in relation to that of R1, R3, and R6, so that the difference in voltage should not be very large (probably only about 1 volt or less at a rough estimate). A substantially lower voltage would suggest a fault in R8 or C1, although there could conceivably be other causes.

The next voltage checks can be made in a more or less random fashion, but in the interests of not accidentally missing something out it is advisable to take a more methodical approach. For example, start at the input of the unit and gradually work through to the output. In this case the input stage is based on the transistor at pins 6, 7, and 8 of IC1. Although this transistor is part of an integrated circuit, the LM389N is an unusual device in that as well as an audio amplifier stage it contains three transistors with each one having its three terminals fully accessible. These transistors can therefore be regarded as ordinary silicon npn transistors as far as voltage checks are concerned.

R1 and R2 provide a bias voltage to the base of the input transistor, and with R1 at about three times the value of R2 this gives approximately one quarter of the supply voltage at the base of this device. Assuming a supply voltage of 8 volts (allowing for a 1 volt drop through R8) this gives a test voltage of roughly 2 volts. Obviously, the exact voltage could be significantly different in practice, due to the tolerances of R1 and R2, the fact that the battery voltage is unlikely to be exactly 9 volts, and so on. Two other points have to be taken into account in this case. One is the input resistance of the transistor, and this is effectively in parallel with R2. This resistance is roughly equal to the value of R4 multiplied by the current gain of the transistor, and with the typical current gain of the transistor being some 275 the input resistance is far too high to have a substantial shunting effect in this case.

Another factor which must always be borne in mind is the resistance of the multimeter. With a digital or electronic analogue instrument the input resistance is usually about 1 megohm or more, and is normally too high to be of significance. Things are different for an ordinary analogue multimeter which has a typical sensitivity of 20k per volt. In other words, the resistance of the meter (in ohms) is equal to 20,000 multiplied by the full scale voltage. The input resistance therefore varies from one voltage range to another, but if we assume that the meter is switched to the 5 volt range when making this measurement, it will have a resistance of 100k ( $20,000 \times 5 = 100,000$  ohms or 100k).

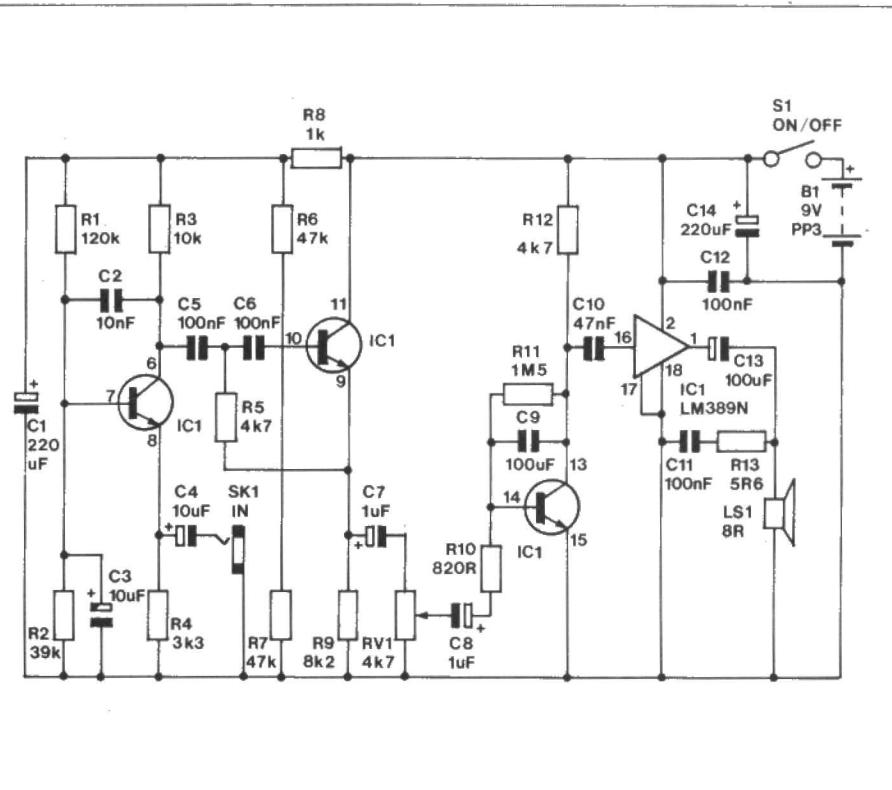


Figure 2. Telephone Amplifier Circuit

This resistance is in parallel with R2 when the voltage check is being made, and would reduce the effective resistance of R2 to only about 28k. The result on the voltage reading would be to reduce it to something in the region of 1.5 volts. In practice any voltage reading in the range 1 to 2 volts made using a 20k per volt multimeter would be quite acceptable, or with a high impedance voltmeter anything from around 1.5 to 2.5 volts would be satisfactory.

If an obviously unsatisfactory voltage reading was obtained it would then be necessary to use this as a pointer towards the precise cause of the fault. Suppose the voltage reading was around 0.65 to 0.7 volts, this would tend to suggest that the base/emitter junction of the transistor was operating as a forward biased diode and clamping the junction of R1 and R2 at little more than earth potential. This would in turn suggest that R4 had gone closed circuit, or that the emitter of the transistor had in some way become connected direct to the earth rail. The obvious way of checking this is to measure the voltage across R4. This should be equal to the base potential minus about 0.6 volts or so dropped through the base/emitter junction of the transistor. In this circuit this gives a voltage of typically just under 1.5 volts, and as R4 has a fairly low value an analogue multimeter would not significantly shunt this component and reduce the test voltage. If a voltage reading of zero is obtained this would tend to suggest that the problem is indeed due to R4 going closed circuit, or perhaps due to a solder bridge short circuiting the emitter of the transistor to the earth line. Some simple resistance checks should be sufficient to sort out the precise nature of the problem.

There are other possible causes of a

low base voltage, and these should be investigated if a resistance check indicates that the correct resistance is present in the emitter circuit of the transistor. One possibility is that R2 is low in value or R1 has gone high in value. If R1 had gone very high in value or completely open circuit, temporarily connecting a 120k resistor in parallel with it should produce correct voltages in the circuit. If this had no significant effect it would suggest that R2 had gone very low in value, or perhaps that C3 had become faulty. The possibility of a fault in TR1, such as a closed circuit base/emitter junction could not be ruled out either. This would have to be sorted out by testing these components, and suitable techniques were described in the first article of this series.

If the voltages in the input stage proved to be correct the same techniques could be applied to the next two stages of the circuit. The voltage at the junction R6, R7, etc. should be about half the supply voltage, but this is a voltage that will be significantly reduced if an ordinary analogue multimeter is used to make the measurement. The voltage at the emitter of the transistor should be about half the supply voltage minus about 0.6 volts dropped across the base/emitter junction, and as this voltage is at a low impedance it would not be vulnerable to meter loading. As a result of this, when using an ordinary analogue multimeter to make the checks the voltage at the emitter could appear to be greater than the voltage at the base. A simple check to see if loading effects are giving misleading results, or the voltages really are amiss, the voltage from the emitter to the base of the transistor can be checked. This should show the base to be slightly positive of the emitter (despite what the two previous checks might have sug-

gested). The voltage at the junction of C5, C6 and R5 should be virtually identical to the emitter potential due to the coupling through R5.

The next stage has a different method of biasing with just a single resistor being used. However, with this type of circuit the biasing is normally arranged so that the collector voltage is at something in the region of half the supply voltage, and anything from about 1 volt to a volt or so below the positive supply voltage would in fact be perfectly acceptable. The base bias resistor (R11) has a very high value, and even using an electronic multimeter of some kind this could give a reading of significantly less than the true base voltage of about 0.65 volts. With an ordinary analogue multimeter there would be little more than zero reading.

## Output Stage

Integrated circuits often give problems when it comes to voltage testing since detailed information on the internal circuit is often lacking. Even where this information is available it can be difficult to work out likely test voltages due to the circuit complexity and the use of circuits that are often quite unconventional by discrete standards. In many cases though, detailed information on the integrated circuit is not required. The output stage of this circuit should give a quiescent output voltage of about half the supply potential, and it should be within about half a volt of this figure. Audio output stages have to be designed in this way in order to give the maximum possible unclipped output voltage swing.

If the output voltage at pin 1 of IC1 is outside the acceptable range it should not

be automatically assumed that IC1 itself is at fault. The audio amplifier section of IC1 has a built-in bias circuit and requires no external bias components. In fact it is essential that DC biases are kept away from the input of the circuit, and this is the reason for the inclusion of C10 in series with the input of the device. If C10 should become leaky, or a DC bias should find its way to the input of the amplifier in some other way, this would almost certainly send the quiescent output voltage well outside its normal range.

A short circuit to one or other of the supply rails, or C13 going closed circuit (which would practically short circuit the output to the earth rail) could also do this, although such a fault would give the unit a very high current consumption and IC1 would become quite warm, which is where we came in.

## AMENDMENTS TO 1985 CATALOGUE

**S-BAY DIRECTOR AERIAL**  
**XQ38R** (Page 25). The front/back ratio quoted in the specification table is actually 17-27dB. The Acceptance angle is  $\pm 17-28^\circ$ .

**14-BAY DIRECTOR AERIAL**  
**XQ43 - 46** (Page 25). The group headings for the specification table have been erroneously shifted left one column.

**21-BAY DIRECTOR AERIAL**  
**XQ50E** (Page 25). Again the acceptance angle is  $\pm 10-24^\circ$ .

**FERRITE ROD AERIAL LB12N** (Page 29). The circuit details of a medium/long wave receiver supplied with this aerial is actually a very old design, recommending the use of germanium transistors for example. To use this circuit successfully a fair amount of modification and replacement of out of date components may be required.

**E.H.T. WIRE XR22Y**  
(Page 79). The copper conductor actually comprises 16 strands 0.2mm dia. and not 7 strands of 0.25mm dia.

**SINGLE-ENDED AND AXIAL ELECTROLYTICS** (Pages 93, 94). The column headings for the specification table at top right of page 93 is transposed with the column headings of the table at top left of page 94.

**1/2in MONO CHASSIS SOCKET**  
**CHROME BEZEL HF90X** (Page 117). This standard 1/4in moulded jack socket does NOT have gold plated contacts.

**UNIVERSAL PLUG HH38R**  
(Page 129). This adaptor lead may or may not include a 2-pin plug and mating 2-pin socket 200mm from the end of the lead, entirely depending on the supplier. To save any further confusion it can be said that the leads are not provided with said plugs/sockets, as this is the case with our current new stock.

### HI-FI DISTRIBUTION BOX

**WY16S** (Page 130). The four way Euroboard is fitted with 1 metre of 3-core mains cable, and not 2½ metres as stated in the description in the catalogue.

**SECONDARY LINE JACK UNIT**  
**FG28F** (Page 132). This item has been described as a Secondary Line Jack Unit (2/4A), whereas it should be (2/6A).

**MINIATURE TIE-CLIP**  
**MICROPHONE YW71N** (Page 185). This tie-clip microphone is NOT supplied with a battery as stated in the catalogue.

**LOW-COST PHOTO-TRANSISTOR YY66W** (Page 198). This device now has a TIL78 package and not TO106, and has only two leads for collector and emitter. The collector is denoted by a flat on the package and the shorter of the two leads. Electrical characteristics are Light Current at 940nm V<sub>ce</sub> = 5V, H = 20mW/cm<sup>2</sup>, 7mA; Dark Current at V<sub>ce</sub> = 30V, < 0.1nA; Peak Spectral Response, 940nm.

**40W STEREO AMPLIFIER**  
**XH48C** (MES33). (Page 232). We regret that it has become necessary for us to discontinue kit XH48C. Some of the special parts are no longer available. Please check before commencing construction that all the parts you are going to need are available and order any that appear on page 232 of the 1985 catalogue at once, as all these items will be discontinued when all present stocks are exhausted (i.e. are currently 'while stocks last'). If you are now unable to complete this project as a result of our inability to supply all the parts, we

will consider requests for refunds, and you should write at once giving full details of your claim to:

The Sales Manager,  
Maplin Electronic Supplies Ltd,  
P.O. Box 3,  
Rayleigh,  
Essex SS6 8LR.

**ZX SPECTRUM KEYBOARD KIT**  
**LK29G** (Page 267). Although the ready made keyboard includes the adaptor and case, the kit does not.

**UF04E** (Page 307). In the table of order codes UF04E has been described as 4049UBE, whereas it should be 74HC4049.

### QUAD BUFFERS 3-STATE

**74LS125 YF49D** (Page 308). The internal architecture and pin outs diagram is implied as belonging to the 74LS124; it should of course be the 74LS125.

**1-POLE 8-WAY ANALOGUE SWITCHES QW34M, UF06G & UF14Q** (Page 319). The captions of the pin-out diagrams for these devices are transposed. The 74HC4251 is actually in the 18-pin package and the 4051BE and 74HC4051 have the 16-pin package.

### DIGITAL SOUND EFFECTS GENERATOR PCB YQ42V

(Page 341). Full details of the various circuit applications of the Digital Sound Effects Generator are NOT supplied with the PCB as stated in the catalogue.

**2732 32K EPROM** (Page 370). The 2732 32K EPROM is quoted as having an access time of 250ns, whereas in actual fact it has a minimum of 350ns. For most practical purposes it can be assumed to be 450ns and

suitable for use with micro-processors having a 500ns clock period.

**AXIAL FAN WY08J** (Page 381). The supporting 'spider' will be composed of aluminium and not zinc alloy as stated in the catalogue.

**STANDARD STEREO HEADPHONES WF13P** (Page 385). The photograph is now out of date. These headphones do not have a padded headband and the lead is straight not coiled.

### DUAL-IN-LINE SWITCHES

**XX26D - XX29G** (Page 394). The photographs showing these DIL switches, and the 8-way type in particular, are no longer current. The switches now come in a white encapsulation with the sliders numbered 1 to 8 in black; the sliders are correspondingly colour coded brown, red, orange, yellow, green, blue, violet, grey.

**KEYBOARD CASES YJ15R & YJ14Q** (Page 400). The case YJ15R is actually for the keyboard without numeric key-pad YJ12N, and case YJ14Q is to house the keyboard with numeric pad YJ13P. Prices are correct.

**THYRISTOR MCR102 QH43W**  
Although it is still currently in use in our Train Controller Kit, this device has been while stocks last for some time; it has not appeared in either the 1984 or 1985 editions of the catalogue. However a fair quantity still remains in stock. The MCR102 has the following specifications:

Case style - TO92f  
PIV - 30V  
IT (r.m.s.) - 0.8A  
VGT (max.) - 0.8V  
IGT (max.) - 0.2mA  
IH (max.) - 5mA  
Price 59p.

# Control-a-Train

- ★ Pulse Width Modulated For Excellent Low Speed Performance
- ★ Inertia Control of Momentum and Braking
- ★ Box or Panel Mounted
- ★ Easy To Build
- ★ Low Cost

by Robert Penfold



We make no apologies for using three of Mr. W. Sharman's superb photographs of steam engines with his kind permission in this article about model trains, but we're all steam train nuts here at Maplin and we just loved the pictures!

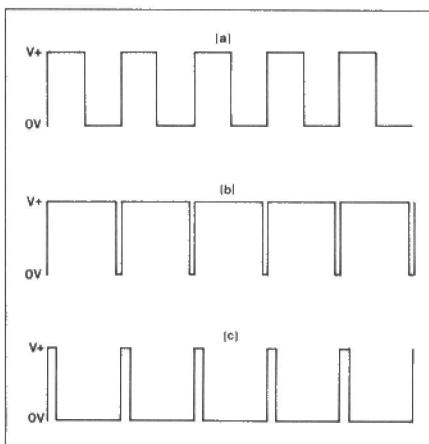
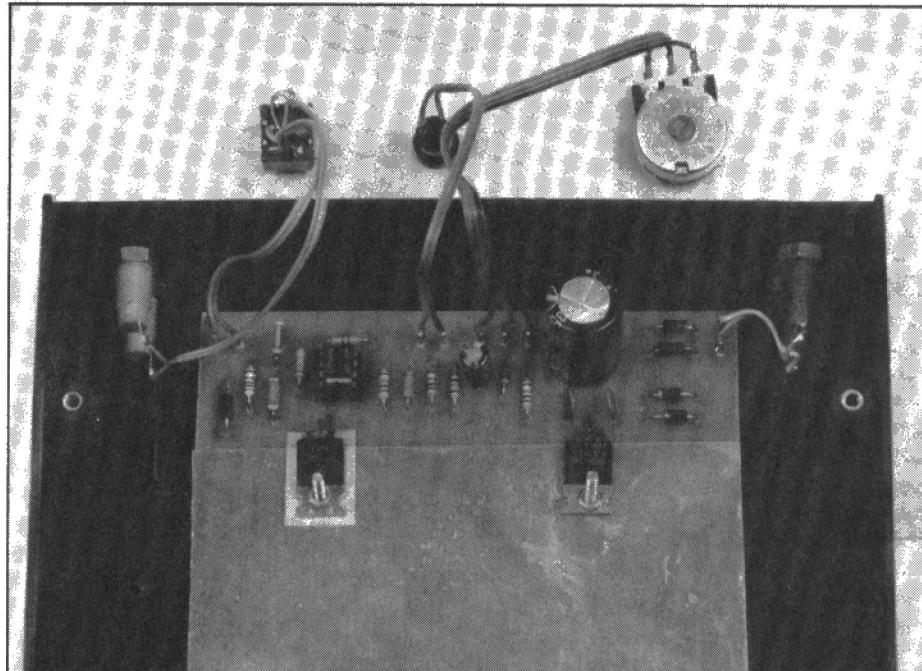
Things have moved on from the days when model train controllers were little more than a rectifier and a high power potentiometer (called a 'rheostat'), and using modern electronic devices it is possible to produce a simple controller that has quite advanced facilities. This design is based on just two operational amplifiers but it has a pulsed output for good starting and low speed performance, plus simulated inertia, momentum and braking. It also has output current limiting which protects the circuit when the inevitable overloads and short circuits occur. The unit is designed to operate from the 15 volt AC output from a train transformer or the 15 volt AC auxiliary output of a train controller but it could easily be built as a self contained unit having a built-in mains transformer if preferred. It should also run properly if powered from the 12 volt DC output of a train transformer or controller.

## Pulsed Control

Obtaining good results from a model train controller is more difficult than it might at first appear. Simply varying the voltage fed to the motor by means of a voltage regulator type circuit or a series rheostat might seem to offer excellent performance but in practice, the characteristics of the electric motor leads to problems. Starting tends to lack realism as a fairly high voltage is needed by the motor before it will start to operate but once it does start to run, only a relatively low voltage is needed in order to move the train slowly. As a result the train suddenly jumps to a high speed instead of having slow and realistic acceleration.

Another problem is that of poor low speed performance. This tends to be worse in the rheostat type of controller where the output impedance of the controller is inevitably quite high at low and medium speeds due to the high series resistance of the rheostat. This results in the output voltage actually decreasing slightly if the train comes to an incline and the current consumption rises as the motor is loaded more heavily. This prevents the motor from obtaining the increased power that it requires for stable running. If the train goes down an incline, the opposite occurs with the motor requiring less power, drawing less current but receiving increased voltage and a power level that is little changed. The practical result of this is a tendency for the train to run fast down the slightest of gradients and to stall when climbing a gradient.

A constant voltage type controller uses a voltage stabiliser circuit to eliminate these unwanted output voltage variations. This does not totally eliminate the problem though since the power level received by the motor still does not vary in a way that exactly matches its requirements. One way around the problem is to use an over-compensated voltage stabiliser, which is the method of

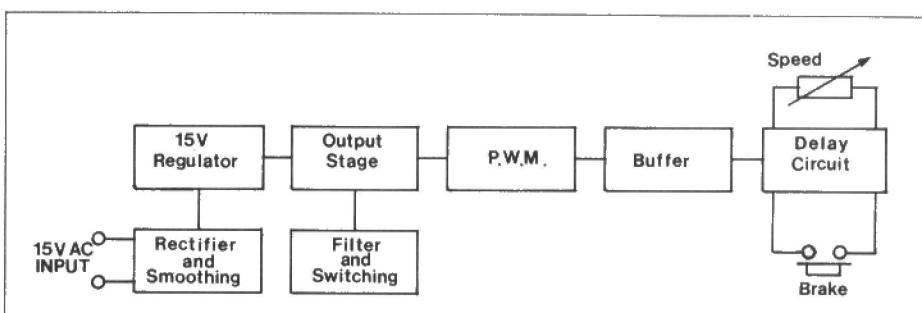


**Figure 1. Output Waveforms;**  
**(a) Half, (b) Max & (c) Min Power Output**  
speed stabilisation used in applications such as cassette recorders. What is probably a more simple and practical solution for the present application and the one which is used here, is a method of pulse control.

The idea of a pulsed output controller is to provide a series of output pulses that drive the motor at full power. The average output voltage (and thus the speed of the train) is varied by altering the mark-space ratio of the output signal. Figure 1 helps to explain the way in which this system operates.

This diagram shows typical output waveforms at various output powers. In figure 1 (a), the waveform is a square-wave having a 1 to 1 mark-space ratio. The average output voltage is therefore equal to half  $V_+$  and this gives half maximum output power. In figure 1 (b), the mark-space ratio of the signal is very high and the output is at  $V_+$  for the vast majority of the time. This gives an output power which is virtually equal to that obtained if the output was at  $V_+$  continuously. There is obviously a small power loss due to the brief periods when the output goes low but these are too short to give a significant power loss in practice and can be ignored. Finally, in figure 1 (c), the output consists of very brief pulses and most of the time the output is at zero volts. This gives a very low average output potential and would in fact fail to turn-over the motor at all.

Although small DC electric motors are not designed to operate from a pulsing supply, they will do so perfectly well provided the output frequency is not very low or very high. A frequency of a few hundred Hertz is satisfactory. In a train controller application, excellent results are obtained as the brief but powerful pulses nudge the train into movement and overcome the starting problem and the tendency to stall at slow speeds.



**Figure 2. Block Diagram**

## Operating Principle

The block diagram for the controller appears in figure 2. The 15 volt AC input is rectified and then smoothed. A 15 volt regulator circuit is used to give a reasonably well smoothed and stabilised supply for the main circuit, although such a well smoothed and regulated supply voltage is by no means essential. The main reason for including the regulator is that it incorporates current limiting which protects the unit as a whole in the event of a short circuit or other overload on the output.

A pulse width modulator circuit is at the heart of the unit and this is an oscillator which has the mark-space ratio of its output signal controlled by an input voltage. Within the operating limits of the control voltage, the higher the control voltage, the higher the mark-space ratio of the output signal. A buffer stage at the output of the pulse width modulator enables the fairly high currents required by the motor to be comfortably accommodated. The speed of the train can be controlled by varying the input voltage to the pulse width modulator.

For straightforward speed control, a potentiometer to provide the control voltage is all that is required. In order to give simulated inertia and momentum a delay circuit must be added. This should give a fairly long attack time so that the acceleration of the train is restricted to a realistic level. With the power removed, a real train will coast for a considerable distance and an even longer decay time is required. However, the simulated braking is provided by a push button switch that can greatly reduce the normal decay time of the delay circuit.

Although the output signal is a pulsed signal there is little problem with radio frequency interference being generated due to the low voltages and low fundamental frequency of the output signal. A simple filter is included at the output to attenuate the weak high frequency harmonics that are generated and the direction control (a switch that controls the polarity of the output signal) is also included.

## Circuit Operation

For a unit of this type, very few components are required as reference to the circuit diagram of Figure 3 will reveal. In this circuit, IC2b is used as virtually an ordinary operational amplifier relaxation oscillator. The motor will require a fairly high current of typically about 500 milliamps and Darlington power transistor TR1 is used as an emitter follower buffer stage to enable suitably high output currents to be supplied. D6 and C6 are suppression components and S1 is the direction control.

The basic action of this type of oscillator is for C5 to charge to a little over half the supply voltage via R7 and so on, with a squarewave being generated

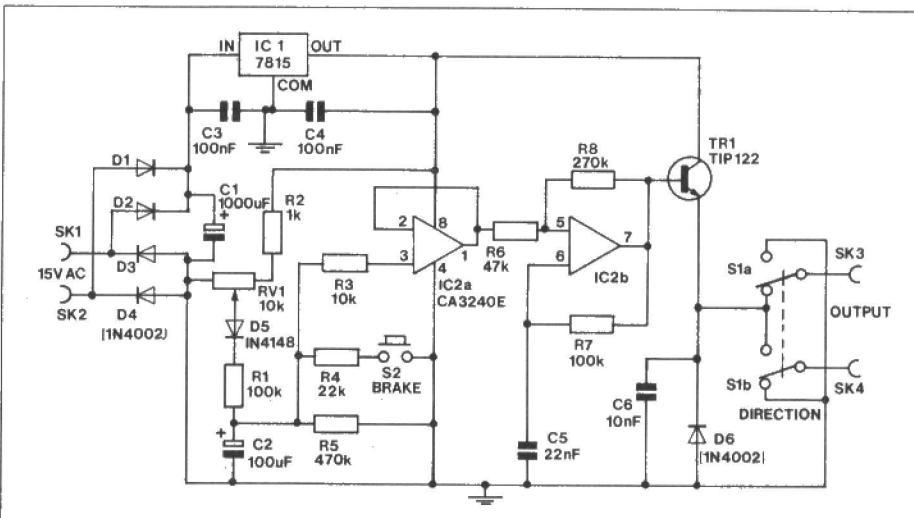


Figure 3. Circuit Diagram

at the output of the operational amplifier. This assumes that the input bias voltage to R6 is half the supply voltage but in this case, the bias can be varied and variations in this potential have the effect of altering the output waveform. In fact the effect on the waveform is to give an average output voltage that is roughly equal to the bias voltage. Thus the speed of the train can be controlled simply by controlling the bias voltage to the oscillator and the required pulsed output is obtained.

IC2a is used as a buffer in the bias voltage circuit and RV1 is the speed control. D5, R1 and C2 are a timing circuit which limit the acceleration of the train, giving the simple simulated inertia effect. When RV1 is backed-off, the only significant discharge path for C2 is through R5 and the train only reduces speed very gradually, giving the simulated momentum. Closing S2 shunts R4 across R5, giving a much faster reduction in speed and S2 therefore gives the simulated braking action. The specified



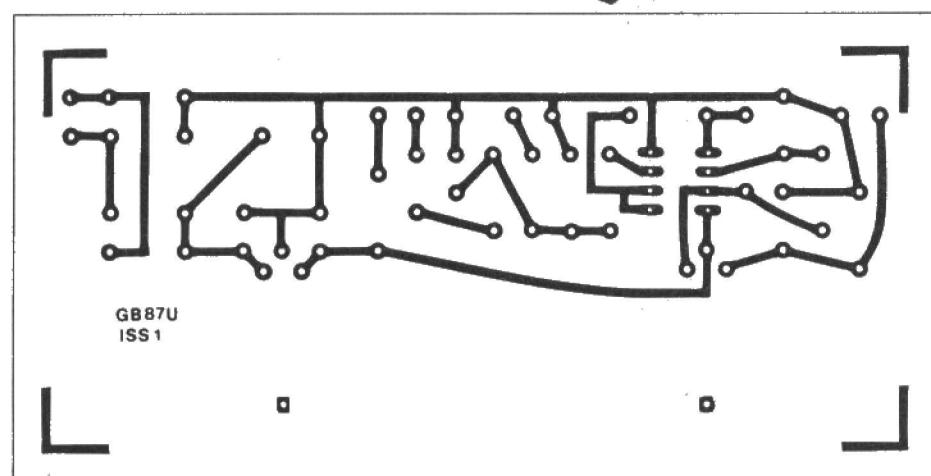
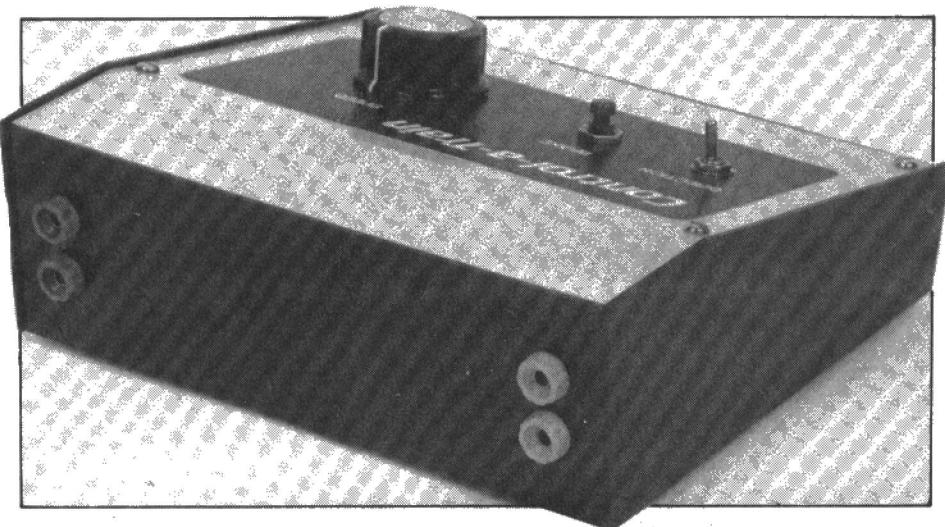


Figure 4. PCB Artwork

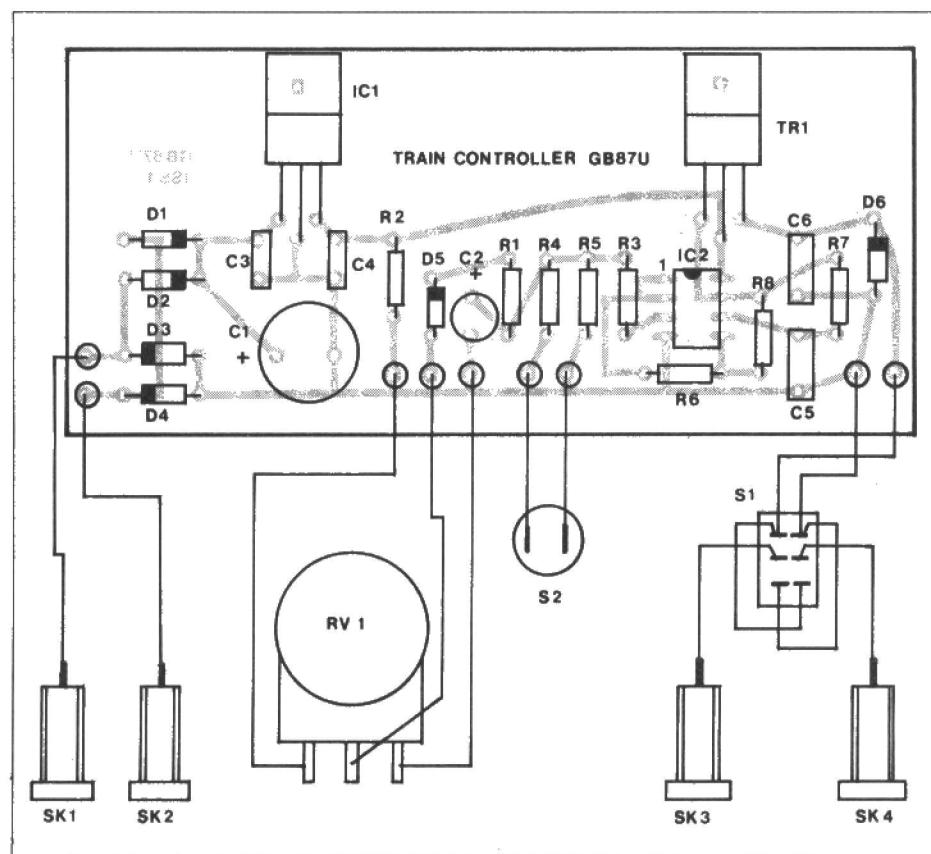


Figure 5. PCB Wiring and Legend

values will give excellent results but by altering the values of R1, R4 and R5, the inertia, momentum and braking characteristics can be tailored to suit individual requirements.

As explained previously, power is obtained from a 15 volt AC output of a train transformer or controller and this output should be rated at about 1.4 amps or more. The rectifier is a bridge type (D1 to D4) and C1 is the smoothing capacitor. The supply stabilisation is provided by the monolithic voltage regulator IC1 and this enables output currents of up to 1 amp to be provided. This is adequate for any of the popular small model railway gauges but owners of large gauge layouts should note that it might not be adequate for their purposes.

## Construction

Start by making up the printed circuit board. Figure 4 and Figure 5 gives full details of both the printed circuit board and the hard-wiring. IC2 is a MOS input device and it would be prudent to observe the basic anti-static handling precautions when dealing with this component. Leave it in its protective packaging until the unit is otherwise complete and it is time for it to be connected into circuit. The device should then be fitted in a holder and handled as little as possible. Fit Veropins at the point where connections to the controls and sockets will be made and take care to fit the electrolytic capacitors and semiconductors the right way around.

TR1 and IC1 are both mounted horizontally on the board and a piece of (approximately) 18 s.w.g aluminium is sandwiched between these components and the board. This aluminium fin should have dimensions of about 112 by 85 millimetres and it acts as a heatsink for TR1 and IC1. As TR1 operates in a switching mode, it actually dissipates only a modest amount of power but IC1 does have to dissipate several watts when the train is run at speed and without adequate heatsinking, it could be damaged. The printed circuit board can be used as a sort of template when marking the positions of the mounting holes in the heatsink. Position the piece of aluminium so that the metal undersides of TR1 and IC1 are fully in contact with it but the aluminium fin should not overlap the board so far as to risk it short circuiting to the leadout wires of either device.

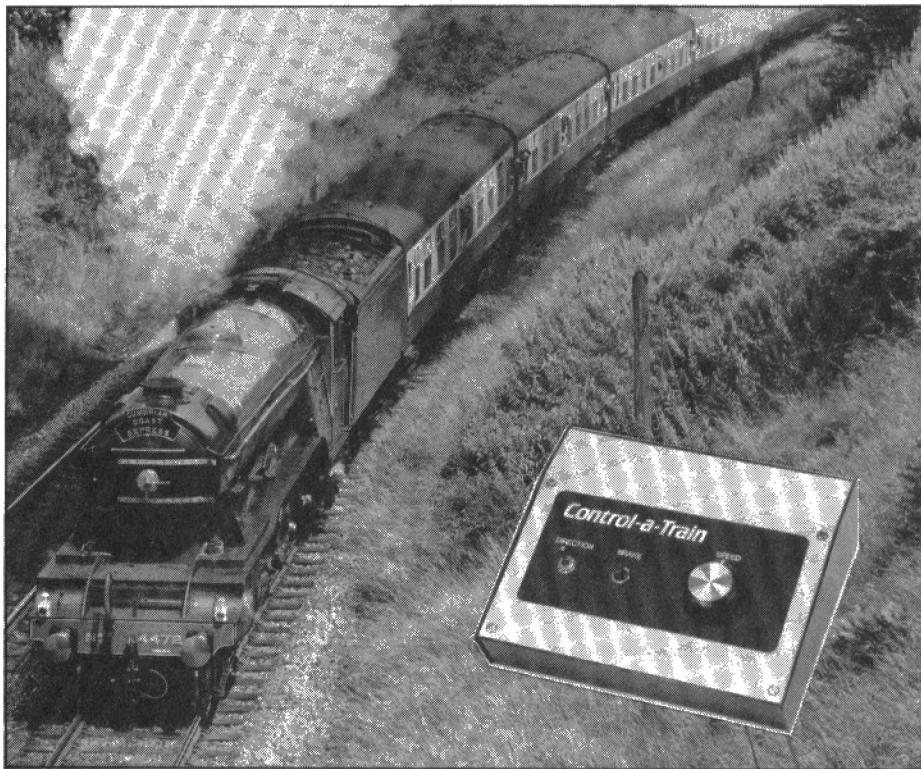
IC1's heatsink-tab connects internally to its common terminal and thus to the negative supply rail of the controller. The heatsink-tab of TR1 connects internally to its collector terminal and therefore to the +15 volt line. In order to prevent a short circuit on the 15 volt stabilised supply, one or both devices must be insulated from the heatsink using a standard plastic TO-66 insulating kit. Probably the best solution is to insulate only TR1, leaving the heatsink at the negative supply potential. The insulating

washer fits between TR1 and the heatsink with the plastic bush fitted on top of TR1 and into its mounting hole. In other words, the washer must insulate TR1 from the heatsink and the bush must insulate TR1 from the mounting bolt.

The board is secured to the base panel of the case by means of the mounting bolts for TR1 and IC1, which should be 1 inch long 6BA types. Also,  $\frac{1}{4}$  inch spacers are included on the mounting bolts between the base panel and the printed circuit board. The assembly is mounted with the board well to the rear of the case leaving sufficient room for the heatsink in the front part of the case. Once the board and heatsink have been mounted in the case, use a continuity tester to check that the insulating kit on TR1 is effective.

It is obviously not essential to use the sloping front case specified in the Parts List but this is the ideal type of case for a train controller and the suggested type is about the optimum size. The three controls are mounted on the front panel. SK1 and SK2 are mounted at one end of the rear panel while SK3 and SK4 are fitted at the opposite end of this panel. (See Figure 5.) To complete the unit the point to point style wiring is then added using ordinary multi-strand connecting wire.

If the controller is to be constructed as a mains powered unit with a built-in mains transformer, a substantially larger case will be required. The mains transformer should have a rating of 15 volts at 1.4 amps or more and the Maplin TR34V HP type (Order Code WB22Y) would be suitable. The 15 volt tapping of one secondary winding would feed the controller circuit while the other winding could be used to provide a 15 volt AC auxiliary output. An important point that must be emphasised here is that the



normal safety precautions for mains powered equipment must not be ignored. The case should be a type having a screw fitting lid so that easy access to dangerous mains wiring is not possible. Also, the negative supply rail of the unit plus any exposed metalwork such as fixing screws should be earthed to the mains earth lead.

## Using the Controller

SK1 and SK2 connect to the 15 volt output of the train controller. SK3 and SK4 connect to the power rail. Make quite sure that you do not accidentally reverse these two sets of connections as this would almost certainly damage some of

the components. When set for minimum power, there is actually a low output power to the train and a slight hum might be produced from the motor. The train should not move though and should be well below the start-up threshold power level.

Excellent starting and low speed performance should be achieved but only if the track is kept clean so that the engine is always in good electrical contact with the track. Controllers of this type can be a little difficult to master if you have previously only used a simple type but so would driving a real train and the higher level of skill required is the whole point of inertia type controllers.

## CONTROL-A-TRAIN PARTS LIST

### RESISTORS: All 0.4W Metal Film

R1,7	100k	2	(M100K)
R2	1k	1	(M1K)
R3	10k	1	(M10K)
R4	22k	1	(M22K)
R5	470k	1	(M470K)
R6	47k	1	(M47K)
R8	270k	1	(M270K)
RV1	10k Pot lin	1	(FW02C)

### CAPACITORS

C1	1000 $\mu$ F 35V PC Electrolytic	1	(FF18U)
C2	100 $\mu$ F 25V PC Electrolytic	1	(FF11M)
C3,4	100nF Ceramic Minidisc	2	(YR75S)
C5	22nF Carbonate	1	(WW33L)
C6	10nF Carbonate	1	(WW29G)

### SEMICONDUCTORS

D1-4,6	1N4002	5	(QL74R)
D5	1N4148	1	(QL80B)
TR1	TIP122	1	(WQ73Q)
IC1	$\mu$ A7815UC	1	(QL33L)
IC2	CA3240E	1	(WO21X)

### MISCELLANEOUS

SK1,2	4mm Socket Red	2	(HF73Q)
SK3,4	4mm Socket Blue	2	(HF70M)

S1  
S2

### OPTIONAL

D.P.C.O Sub-min Toggle	1	(FH04E)
Push Switch	1	(FH59P)
Printed Circuit Board	1	(GB87U)
DIL Socket 8-pin	1	(BL17T)
Kit (P) Plas	1	(WR23A)
Pin 2148	1 pkt	(FL24B)
Knob K7B	1	(YX02C)
Bolt 6BA 1in	1 pkt	(BF07H)
6BA Spacer $\frac{1}{4}$ in	1 pkt	(FW34M)
6BA nuts	1 pkt	(BF18U)
10-way Ribbon Cable	1 mtr	(XR06C)
Control-A-Train Front Panel	1	(FT40T)
Control-A-Train Heatsink	1	(FT53H)

ABS Console M6006	1	(LH66W)
4mm Plug Red	2	(HF66W)
4mm Plug Blue	2	(HF63T)

A kit of above parts (excluding optional items) is available.  
Order As LK64U (Control-A-Train Kit) £10.99

The following parts are also available separately, but do not appear in the 1985 catalogue:  
Control-A-Train Front Panel Order As FT40T Price £1.75  
Control-A-Train PCB Order As GB87U Price £1.99  
Control-A-Train Heatsink Order As FT53H Price 38p

# SCINTILLATING SIX

## Temperature Alarm

Temperature alarms can be used in a variety of applications from such things as monitoring the temperature of machinery and sounding the alarm if overheating occurs, to activating the alarm when an electric kettle reaches a certain temperature. Circuits of this type can also function as a simple form of fire alarm.

The circuit shown here covers a wide temperature range that extends from around 20 degrees Centigrade to over 100 degrees Centigrade. The temperature sensor is a VA1056S negative temperature coefficient thermistor. This has a resistance which varies from about 47k at 20 degrees Centigrade to under 1k at 150 degrees Centigrade. The thermistor is connected as one section of a potential divider, with the other arm formed by the series resistance of R1 and RV1. This gives an output voltage that rises and falls in sympathy with changes in the temperature of TH1. The output of the sensor circuit is fed to a trigger circuit based on IC1a and IC1b. IC1 is a CMOS 4001BE quad 2 input NOR gate, but these two sections of the device are connected as inverters. When the output from the

sensor circuit exceeds a certain level (about 50% of the supply voltage) the output of IC1a switches to the low state and the output of IC1b goes high. A 5 volt stabilised supply is used for IC1 so that the switch-over voltage (and threshold temperature) is not significantly affected by the changes in the battery voltage. The stabilised supply is provided by monolithic voltage regulator IC2.

The alarm signal is generated by IC3 which is a standard 555 astable circuit, apart from the fact that a 7555 CMOS version of the device is used in order to give a low current consumption. The output of IC3 drives a Piezo ceramic resonator. When mounted in free air, this has only a very low sound output level but when mounted on a case, it can give quite a piercing alarm sound. IC3 is gated on by the high output signal from IC1b when the unit is activated. This drives the reset input of IC3 rather than controlling the supply to the device.

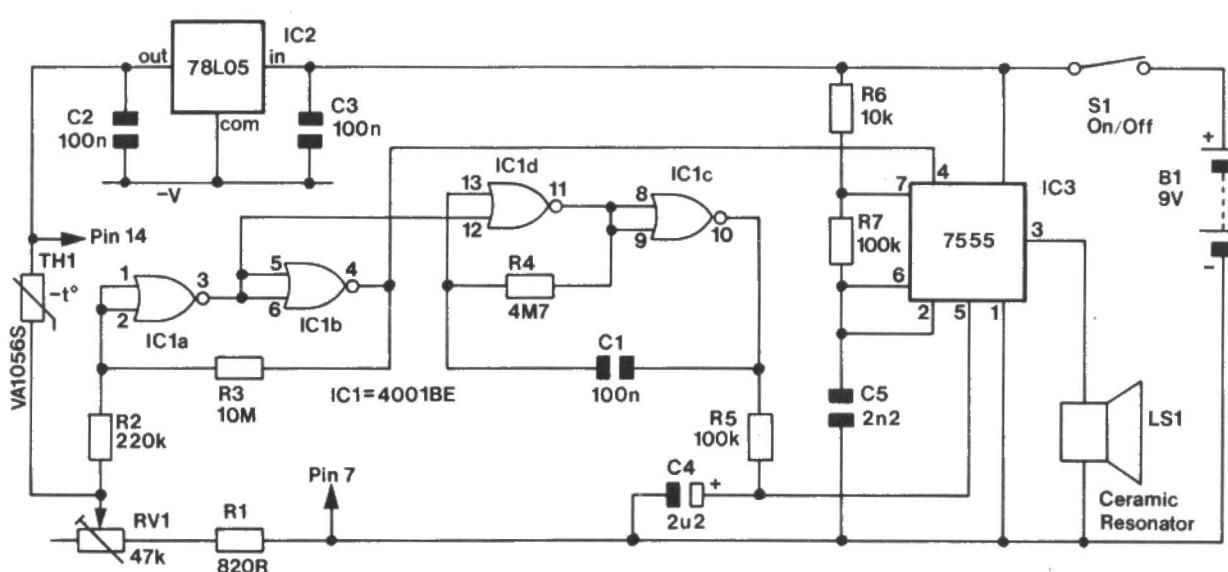
In order to make the alarm signal more effective the tone generator is frequency-modulated. The low frequency modulation signal is generated by a gated astable circuit formed by the

remaining two gates in IC1 together with timing components R4 and C1. This astable is gated on by the low output signal from IC1a when the unit is activated. The output from IC1d is a roughly square waveform, but this is filtered by R5 and C4 to give a waveshape that is virtually triangular. This produces an output signal which has its frequency swept smoothly up and down, generating an excellent alarm sound. The modulation signal is coupled direct to the threshold input of IC3.

RV1 must be adjusted so that the unit is activated at the correct temperature; and to achieve this TH1 must first be subjected to the required threshold temperature (which should not be difficult to arrange in practice). Start with RV1 at minimum resistance and then slowly adjust it for increased resistance until the alarm is activated.

In most applications a small 9 volt battery will be adequate as the power source. However, if the unit is to be left running for long periods of time, it would be preferable to use high capacity Ni-Cad cells as the power source or to use a mains power supply unit.

by Robert Penfold



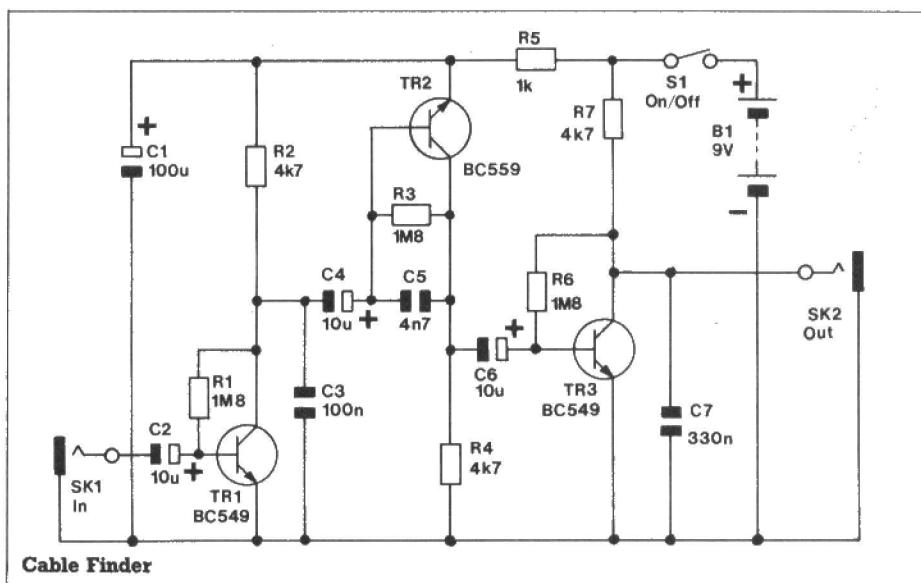
Temperature Alarm

## Cable Finder

It is a good idea to trace wiring in walls prior to the more usual course of drilling and hoping for the best. The two basic methods of tracing cables are the metal detector system and the so-called 'hum' type locator. Metal detector systems have the advantage of not requiring any current flow in the wiring being traced, but to be really effective a fairly sophisticated circuit is required and simple types can be totally useless in practice. Hum locators require a current flow in the cable being traced as it is the field that the current produces rather than the cable itself that is really being traced. Their advantage is that they are very inexpensive and simple, but nevertheless give good results in most cases. It is a hum locator type cable tracer that is featured in this article.

Devices of this type are little more than a high gain amplifier fed from an inductor and driving an earphone or a pair of headphones. This circuit is designed to drive a crystal earphone from SK2, and the use of any other type of headphones is not recommended. The inductor can be any fairly high value type (a few millihenries), and a telephone pick-up coil was also found to work quite well.

The circuit consists of three high gain common emitter amplifiers which provide a total voltage gain of more than 100dB. Instability is not a problem as the high frequency response of the amplifier is severely attenuated by filtering capacitors C3, C5 and C7. This does not significantly reduce the sensitivity of the amplifier at the 50Hz mains frequency.



The filtering does attenuate frequencies at significantly more than 50Hz and this has the advantage of reducing the general background 'buzz' level which can often be troublesome. The frequencies in this background pick-up are mostly harmonics at frequencies of a few hundred Hertz.

The unit is quite easy to use, but a little practice is required in order to get the best results from it. As explained previously, some current must be flowing in the cable before the unit can trace it, and in general, the higher the current the easier it will be to follow the path of the cable. A load such as an electric motor also makes things easier by radiating a lot of electrical noise which can be easily picked-up by the unit. Lighting cable is

likely to prove the most difficult to trace as only small loads can be used here due to the low current rating of the cable. The pick-up is directional, rather like the ferrite rod aerial of a transistor radio. You should therefore, find it possible to rotate the pick-up coil to minimise any background interference and maximise pick-up from the cable. A useful point to bear in mind is that the signal received from the cable will be predominantly a deep 50Hz hum, whereas any background interference tends to consist more of a somewhat higher pitched buzzing sound. In order to minimise background interference, it is advisable to mount the unit in a metal case, and to use a good quality screened cable from the inductor to SK1.

## TEMPERATURE ALARM PARTS LIST

### RESISTORS - All 0.4W 1% Metal Film

### CAPACITORS

### SEMICONDUCTORS

### MISCELLANEOUS

## CABLE FINDER PARTS LIST

### RESISTORS - All 0.4W 1% Metal Film

### CAPACITORS

### SEMICONDUCTORS

### MISCELLANEOUS

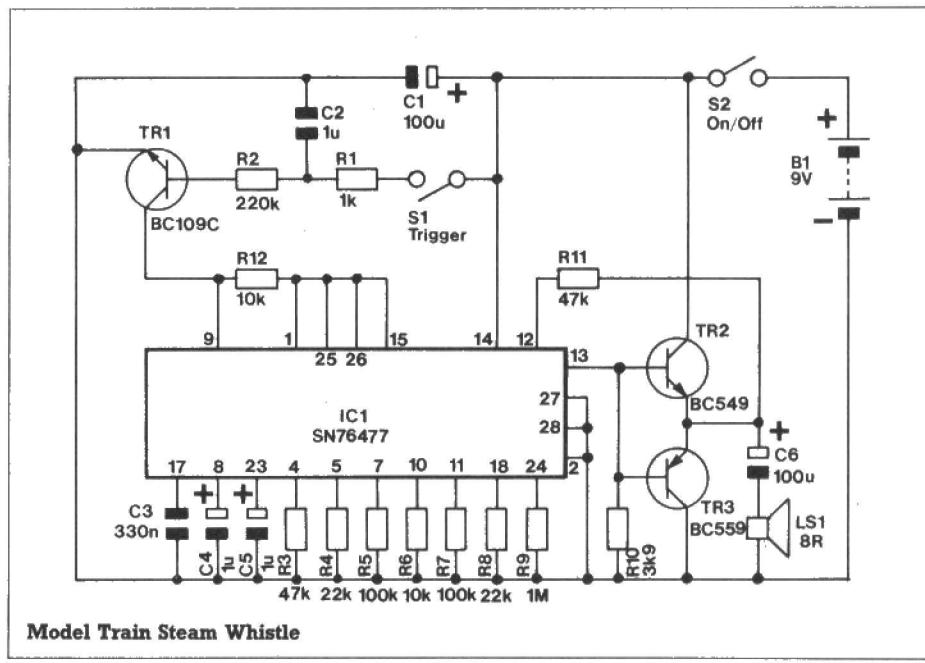
## **Model Train Steam Whistle**

This is a simple sound effects unit for a model railway and it can be manually or automatically triggered. The circuit is based on the very versatile SN76477 sound effects chip which contains a low frequency oscillator (LFO), voltage controlled oscillator (VCO), noise generator, envelope shaper, monostable multivibrator, mixer and driver stage. The only one of these stages which is not utilised in this circuit is the LFO.

A steam whistle sound has two basic constituents; a tone to give the main whistle sound and a white noise sound to give a 'hissing' steam effect. Here we are using the VCO at a fixed frequency to generate the tone and the noise generator to produce the 'hissing' sound. C3 and R8 control the frequency of the VCO while R3 and R4 are discrete components in the noise generator. A simple lowpass filter is included in the noise generator section of the device but in this case, the filtering is not required and no filter capacitor is connected at pin 6.

The attack/decay times of the envelope shaper are controlled by a single capacitor (C4) and separate attack and decay resistors (R6 and R5 respectively). The specified values give a quite fast but considerably less than instant attack, plus a much more gradual decay. The 'hold' period (the time from the start of the signal to the beginning of the decay period) is controlled by the monostable and this has C5 and R9 as its timing components. Overall, this gives a signal of one second or so in duration but this could obviously be lengthened somewhat if desired.

The circuit is activated by taking pin 9 through a high to low transition but this



terminal must be held low for the full duration of the sound. This does not present any problems if the unit is to be triggered manually but it does if triggering must be automatic. The standard method of obtaining automatic triggering is by having a reed switch fitted under the track and a small bar magnet fitted at a strategic position on the train. As the magnet passes over the reed switch, it causes it to momentarily close. Some means of converting this momentary switching action to a longer pulse at pin 9 is required. This is achieved using a simple pulse stretcher and inverter based on TR1. Of course, a push button switch can be used for S1 if manual triggering is preferred or both manual and automatic operation can be obtained by using a

reed switch and a push button type connected in parallel.

The SN76477 has several digital inputs which are used to select the required input signals for the mixer and to set the required control source for the envelope generator. These inputs are either tied to earth or to the +5 volt output at pin 15. In this case, the device is programmed to have the VCO and noise generator selected at the mixer and the monostable as the control source for the envelope shaper.

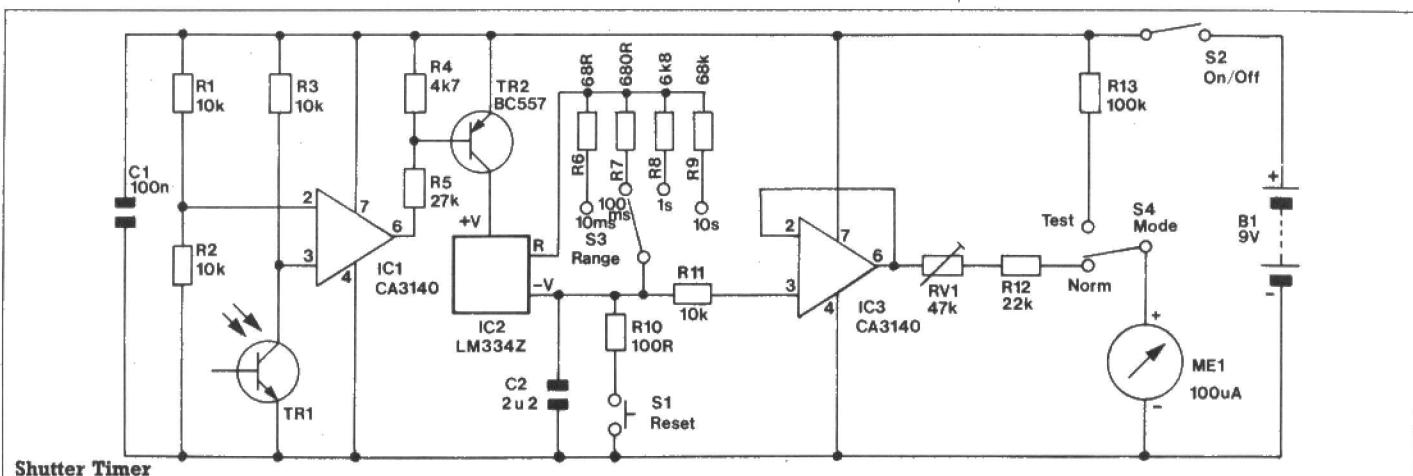
TR2 and TR3 are a complementary output stage which give sufficient drive to produce a reasonable volume level from a small  $8\Omega$  impedance loudspeaker. R10 is a load resistor for the driver stage and R11 is a feedback resistor.

## **Shutter Timer**

The testing of camera shutters is generally carried out with the aid of a highly accurate digital timer and a unit of this type is probably not a practical proposition for most amateur photographers. The low cost alternative featured here is an analogue timer which has four measuring ranges so that quite good

accuracy can be obtained over a wide timing range. In fact, the ranges covered are 0 to 10ms, 100ms, 1s and 10s. The more sophisticated cameras have shutter times from about 4 seconds to 1/2000th of a second, and the timer can therefore be used to check every shutter speed of most cameras. The unit could probably be adapted for many other timing

applications without too much difficulty. The unit works on the principle of a constant charge current to a capacitor, causing a linear increase in charge voltage. In order to give a shutter timer action, it is merely necessary to have a photo-electric circuit that switches on the charge current while the shutter is open with a voltmeter being used to



register the charge voltage. Of course, in practice, the sensitivity of the meter circuit is made variable so that the unit can be calibrated to register the gate time in seconds or milliseconds. The voltmeter circuit must be an ultra high impedance type so that it does not tap off a significant current from the charge capacitor and each reading is held accurately for a reasonable period of time.

IC2 is at the heart of the unit and this is a current regulator device. By means of one resistor, the output current can be set anywhere in the range 1uA to 10mA. In this circuit, four switched resistors (R6 to R9) giving nominal currents of 1mA, 100uA, 10uA and 1uA provide the unit with its four ranges. C2 is the charge storage capacitor and must be a good quality (non-electrolytic) type in order to give consistent results. S1 is the reset switch and when operated, this merely discharges C2 through current limiting resistor R10.

The V+ terminal of IC2 must be connected to the positive supply rail

while the shutter is open but it must be left unconnected at other times and not taken to a low potential or it will provide a discharge path for C2. TR2 is used to provide the necessary switching and this is in turn controlled from the output of IC1 which is an operational amplifier acting as a voltage comparator. R1 and R2 bias the inverting input of IC1 to half the supply voltage while the non-inverting input is fed from the photocell circuit. TR1 is positioned so that it is shielded from a light source (such as a table or desk lamp) when the camera's shutter is closed but is exposed to the light when the shutter opens. This is not difficult to arrange in practice and will probably entail little more than opening the back of the camera and removing the lens if it is an interchangeable type but be careful not to damage the delicate shutter curtains if the shutter is of the focal plane variety. When TR1 is exposed to the light source, it pulls the non-inverting input of IC1 to a low voltage, sending the output low and switching on TR2. TR1 can be virtually any phototransistor incidentally.

IC3 provides buffering to ensure that the voltmeter circuit does not significantly load C2. IC3 is a MOSFET input device which draws no significant input current and gives very steady readings provided C2 is a good quality low leakage component. RV1 is used to calibrate the unit. Probably the easiest way of calibrating the timer is to first connect a push button switch in place of TR1 and to set the unit to the 10 second range. With the aid of a stopwatch or other timepiece, depress the push button for exactly 10 seconds. Finally, adjust RV1 to give precisely full scale deflection on ME1. When S4 is in the 'test' position, the meter has a full scale value of 10 volts and monitors the battery voltage. The battery should be replaced when the reading falls below about 7.5 volts.

Note that camera shutters do not usually have a particularly high degree of accuracy with errors of 20 to 30% being commonplace. Also, the unit will tend to slightly elongate very short shutter times as the photocell is not monitoring a single point but a small area at the film plane.

## STEAM WHISTLE PARTS LIST

### RESISTORS - All 0.4W 1% Metal Film

R1	1k
R2	220k
R3,11	47k
R4,8	22k
R5,7	100k
R6,12	10k
R9	1M
R10	3k9

### CAPACITORS

C1,6	100μF 10V P.C. Electrolytic
C2	1μF Polycarbonate
C3	330nF Polycarbonate
C4,8	1μF 100V P.C. Electrolytic

### SEMICONDUCTORS

IC1	SN76477
TR1	BC109C
TR2	BC549
TR3	BC559

### MISCELLANEOUS

S1	Reed Switch
S2	SPST Sub-min Toggle
LS1	8Ω Speaker
B1	9 Volt Battery (PP9)
	Battery Connector

## SHUTTER TIMER PARTS LIST

### RESISTORS - All 0.4W 1% Metal Film

R1,2,3,11	10k
R4	4k7
R5	27k
R6	68Ω
R7	680Ω
R8	6k8
R9	68k
R10	100Ω
R12	22k
R13	100k
RV1	47k Hor Sub-min Preset

### CAPACITORS

C1	100nF Ceramic
C2	2μ2F Polyester

### SEMICONDUCTORS

IC1,3	CA3140
IC2	LM334Z
TR1	Infra Red Sensor

### MISCELLANEOUS

S1	Push Switch
S2	SPST Ultra-min Toggle
S3	4-Way 3 Pole Rotary
S4	SPDT Ultra-min Toggle
ME1	100μA Panel Meter
B1	9 Volt Battery (PP3)
	Battery Clip
	8-Pin DIL Skt

## Add-on BFO

Many portable radios and cassette units have a shortwave band giving a typical coverage of about 5.5MHz to 15MHz, and this is included primarily for the popular shortwave broadcast bands that fall within these limits. There are also two amateur bands that come within this coverage; 40 metres (7 to 7.1MHz) and 20 metres (14 to 14.35MHz). If you have a suitable portable set, you may well be able to receive many

transmissions on these bands, particularly during daylight hours but it is unlikely that you will be able to resolve them properly. Most transmissions on these two bands are either SSB or CW, which are systems of voice and Morse Code transmission respectively. Both require a BFO (beat frequency oscillator) for proper reception and cannot be resolved using an ordinary AM detector alone. A CW signal may sometimes be readable due to beat notes produced in

conjunction with other transmissions generating an audio output but an SSB signal, although obviously a voice signal, will be distorted to the point where it is totally unintelligible.

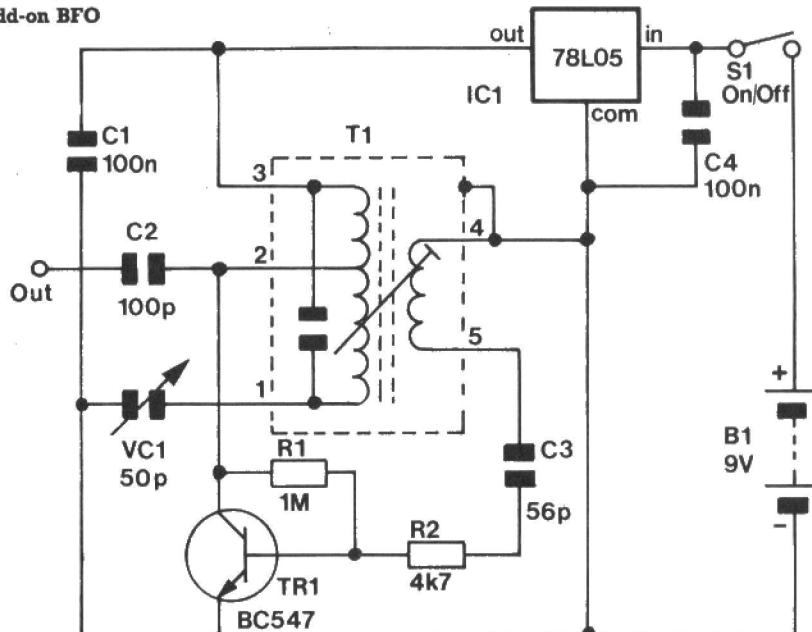
It is usually possible to add a BFO to a portable radio, enabling it to resolve amateur transmissions quite well and in most cases, it is not necessary to make any direct connections to the receiver. A loose coupling using a short wire to radiate the BFO signal should give an

adequate signal transfer. There is insufficient space available here to give details of how SSB and CW signals are resolved, but this topic has been covered in a previous issue of this magazine ('80 Metre Amateur Receiver', issue 10).

The BFO is really just an oscillator which is tunable over a small range of frequencies in the 450 to 475kHz region. Its output is picked up by the intermediate frequency (IF) circuits of the receiver and the set must obviously have an IF in this frequency range. The standard AM broadcast radio IF's are 455kHz, 465kHz or 470kHz and it is highly unlikely that there will be any problems here. The circuit is just a simple transformer feedback type with IF transformer T1 providing the frequency selective negative feedback over common emitter amplifier TR1. R2 and the very low value of C3 prevent excessive feedback or sufficient audio frequency feedback to produce outputs at unwanted frequencies. IC1 provides the oscillator with a well stabilised supply which helps to minimise frequency drift. VC1 enables the circuit to be tuned over a small range of frequencies and this can be used as a sort of 'clarifier' control if accurate tuning using the receiver's tuning control proves to be difficult.

T1 has an adjustable core which must be given a suitable setting using a proper trimming tool (a small screwdriver could damage the core). Adjust-

#### Add-on BFO



ment is probably easiest with the radio accurately tuned to a weak medium wave station. Set VC1 at half maximum capacitance and then place a short wire connected to the output of the unit alongside the radio. By adjusting the core of T1 it should be possible to obtain a beat note and the core is then further adjusted to give a low beat frequency of just a few Hertz.

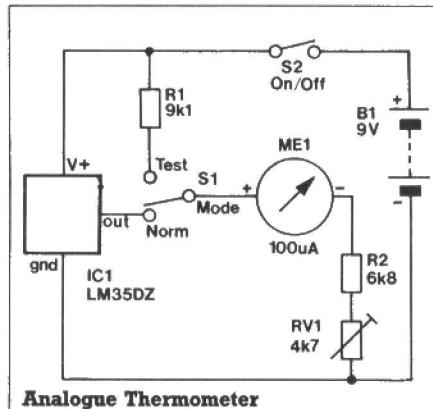
A little experimentation with the position of the coupling wire should soon produce good results. Too little coupling is undesirable as it will give a distorted output. On the other hand, a high level of coupling will operate the automatic gain control circuit of the receiver and only give a low sensitivity. A compromise between these two therefore has to be found.

## Analogue Thermometer

There are many electronic devices that are temperature dependent and while this can often be a disadvantage, it does facilitate accurate electronic temperature measurement. Thermometer designs have in the past often used thermistors or ordinary silicon diodes as the sensor, but recently special integrated circuit temperature sensors and controllers have become popular. These enable reasonably accurate circuits having a minimal component count to be produced. The new LM35 series of devices offer what must be the ultimate in simplicity; a point which is demonstrated by the analogue thermometer circuit featured here.

Most semiconductor temperature sensors provide a voltage or current that changes in a linear manner over a wide temperature range. However, this is not to say that the output voltage is proportional to the applied temperature in degrees Centigrade. There is normally an offset voltage with, for example, a 0 to 100 degree Centigrade range giving perhaps a 2 volt to 3 volt output. The offset voltage (which is 2 volts in this example) therefore has to be eliminated in some way in order to give a truly proportional output.

This problem has been overcome



with the LM35 series of devices, and the version used in this circuit is the LM35DZ which covers a 0 to 100 degree Centigrade range. It gives an output voltage of 10 millivolts per degree Centigrade or, in other words, a 0 to 1 volt output over the full temperature range. Although the guaranteed minimum level of accuracy is not especially good, in practice the device seems to offer a level of performance that is more than adequate for a wide range analogue instrument.

The circuit is basically just the temperature sensor (IC1) driving a voltmeter circuit ME1, R2 and RV1) having a sensitivity of 1 volt. In practice RV1 is used to accurately calibrate the unit. This merely entails setting the

sensor at an accurately known temperature and then setting RV1 for the correct reading on ME1. Ideally the temperature used should be one that represents a reasonably large deflection of ME1 (i.e. about 40 to 100 degrees Centigrade). Note that a stabilised supply is not necessary as IC1 has a wide supply voltage operating range. Neither is it necessary to have a buffer amplifier at the output as IC1 can drive a small load such as a sensitive meter without any significant degradation of accuracy.

When S1 is set to the 'test' mode of operation the meter acts as a 0 to 10 volt reading type, and it measures the supply voltage. Although the LM35DZ will operate with a supply voltage as low as 4 volts it is advisable to replace the battery when its output voltage falls below about 7.5 volts.

If IC1 is used in liquids it is advisable to mount it in a small test tube or some other container that will keep the liquid away from the leadout wires. Some silicon grease can be used to provide a good thermal contact between IC1 and the test tube (or other container) so that the circuit has a reasonably fast response time. However, bear in mind that it will take IC1 at least a few seconds to fully respond to any large temperature changes.

## ADD-ON BFO PARTS LIST

### RESISTORS - All 0.4W 1% Metal Film

R1	1M	1	(M1M)
R2	4k7	1	(M4K7)

### CAPACITORS

C1.4	100nF Ceramic	2	(BX03D)
C2	100pF Ceramic	1	(WX56L)
C3	56pF Ceramic	1	(WX53H)
VC1	50pF Trimmer	1	(FF45Y)

### SEMICONDUCTORS

IC1	μA78L05AWC	1	(QL26D)
TR1	BC547	1	(OO14Q)

### MISCELLANEOUS

T1	IFT14	1	(LB01B)
S1	SPST Ultra-min Toggle	1	(FH97F)
B1	9 Volt Battery (PP3)	1	(PK58N)

Battery Clip

1 (HF28F)

## ANALOGUE THERMOMETER PARTS LIST

### RESISTORS - All 0.4W 1% Metal Film

R1	9k1	1	(M9K1)
R2	6k8	1	(M6K8)
RV1	4k7 Hor Sub-min Preset	1	(WR57M)

### SEMICONDUCTORS

IC1	LM35DZ	1	(UF52G)
-----	--------	---	---------

### MISCELLANEOUS

S1	SPDT Ultra-min Toggle	1	(FH98G)
S2	SPST Ultra-min Toggle	1	(FH97F)
ME1	100μA Panel Meter	1	(RW92A)
B1	9 Volt Battery (PP3)	1	(FK58N)
	Battery Clip	1	(HF28F)

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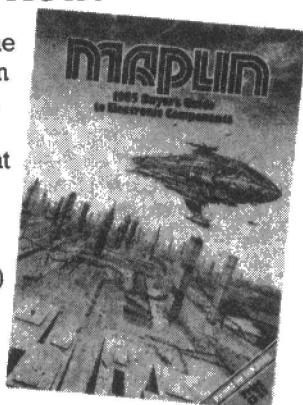
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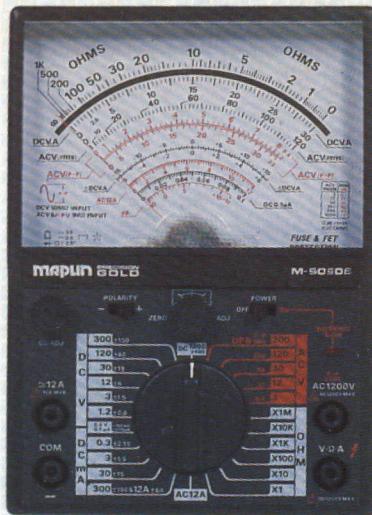
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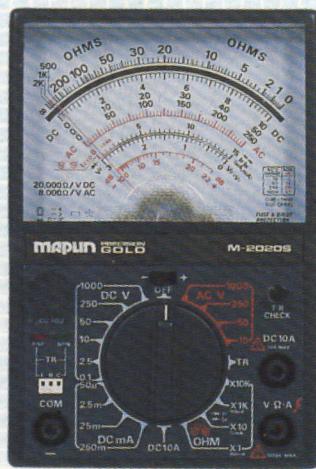


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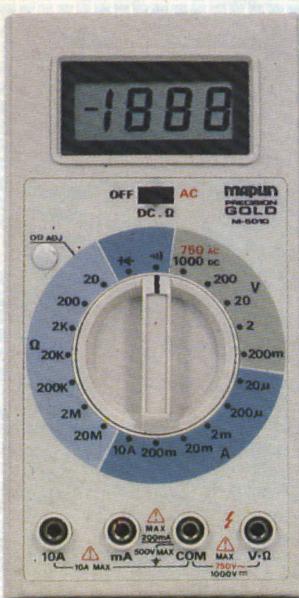
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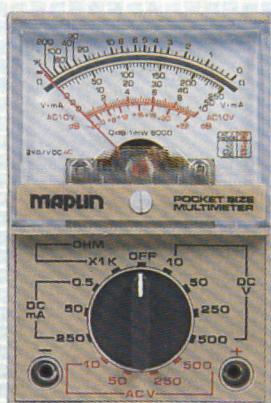


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